U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-268 249

Economic Impacts of Pulp and Paper Industry Compliance with Environmental Regulations Volume III. Appendices to Volume I

Arthur D. Little, Inc., Cambridge, Massachusetts

Prepared for

Environmental Protection Agency, Washington, D.C.

May 77

PB 268 249

EPA 230/3 76 014

ECONOMIC IMPACTS OF PULP AND PAPER INDUSTRY COMPLIANCE WITH ENVIRONMENTAL REGULATIONS

VOLUME III
Appendices to Volume I

MAY 1977

U S ENVIRONMENTAL PROTECTION AGENCY
Office of Planning and Evaluation
Washington, D. C. 20460

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NATIONAL TECHNICAL
INFORMATION SERVICE
U S DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

BIBLIOGRAPHIC DATA SHEET	1. Report No. EPA 230/3-76-014	2.	3. Recipient's Accession No.
4. Title and Subtitle: Economic Impacts of Pulp and Paper Industry Compliance With Environmental Regulations "Appendices to Volume I"			5. Report Date: May 1977 6.
7. Author(s): Peter L. Oliver et al.			8. Performing Organization Rept. No.
9. Performing Organization Name and Address: Arthur D. Little, Inc. 25 Acorn Park Cambridge, Massachusetts 02140			10. Project/Task/Work Unit No. 11. Contract/Grant No.: 68-01-2841
12. Sponsoring Organization Name and Address: Office of Planning and Evaluation Environmental Protection Agency Washington, D. C. 20460			13. Type of Report & Period Covered: Final 14.

15. Supplementary Notes

16. Abstracts

This report estimates the economic impacts of all major environmental regulations on the pulp and paper industry. Regulations covered include: (1) air - state implementation plans and new source performance standards, (2) water - effluent limitations, and (3) noise - OSHA regulations. The main economic impacts estimated are: (1) prices, (2) closure, (3) external financing. Econometric analysis was used to estimate demand and supply curves for the major product sectors. The economics of model plants was used to assess closures and long run prices. A financial funds flow model was developed to estimate cash flow requirements for growth and environmental costs.

17. Key Words and Document Analysis. 17a. Descriptors

Pulp
Paper
Environmental
Economic
Impact
Demand
Elasticity
Capacity
Growth
Prices
Closures

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

18. Availability Statement:	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 175
	20. Security Class (This Page) UNCLASSIFIED	22. Price A08-A01

NTIS-SYS-38 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

ECONOMIC IMPACTS OF PULP AND PAPER INDUSTRY COMPLIANCE WITH ENVIRONMENTAL REGULATIONS

VOLUME III

APPENDICES TO VOLUME I

Prepared by:

Claire R. Canty
Louise M. Firth
Fred D. Iannazzi
Nelson R. Lipshutz
Henry R. Martin
Peter L. Oliver, Project Leader

of

Arthur D. Little, Inc.

Report for

Office of Planning and Evaluation
U.S. Environmental Protection Agency

June 1977

EPA-230/3-76-014

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APPENDIX A

MILL AND PROCESS CHARACTERISTICS

1. Introduction

The major paper industry process steps are pulping (the separation of whole wood into a fibrous mass) and paper making (the formation of discrete fibers into a web, or sheet of paper or paperboard). In addition the paper making process may include additional steps such as sizing, coating and calendering, followed by finishing steps such as slitting, rewinding and sheeting.

Pulping and paper making utilize four basic ingredients: fiber, water, energy and chemicals. Wood remains the dominant fiber source, followed by wastepaper and small amounts of other fibers such as cotton and asbestos. Water is used as a diluent for the pulping and bleaching chemicals, washing the pulp and transporting it through the mill into the paper making operation. All pulp and paper facilities are being pressured by increasingly stringent water pollution control regulations to reduce their water usage rate.

Most mills' energy needs are wholly or partially filled by purchased electricity and fuel; however, most of the integrated chemical pulping facilities fill a large portion of their energy needs by burning the organic wastes from their pulping operations. Chemical requirements and the ability to recover chemicals from process wastes depend upon the type of pulping process employed.

2. Pulpwood Raw Materials

Wood is delivered to the pulp mills in various forms: as logs (generally small diameter), as chips from off-site shipping operations, and as chip, slab or sawdust residues from plywood and sawmills. Most companies derive at least a portion of their wood from their own timberlands, but also rely heavily upon purchased wood from private land owners or federal and state timberlands. Pulpwood is now delivered almost exclusively by truck and rail, since water drives have become uneconomical or unlawful.

The industry subdivides its wood requirements into two general categories: softwood (from coniferous or needle-bearing trees); and hardwood (from deciduous broadleaf trees) to reflect mainly the proportional contents of cellulosic fibers and lignin (the substance which binds the fibers together). Both types, however, vary greatly in hardness and density from species to species.

Softwood is used primarily in products where high strength is required; namely, for linerboard and packaging papers, and for producing groundwood pulp. Because it is 50-100% stronger than hardwood and traditionally in abundant supply, softwood has been the dominant pulpwood source. Hardwood is used nearly exclusively in NSSC pulp and as a blending pulp in nearly all of the bleached paper and paperboard products. While its shorter fiber length makes it weaker than softwood, hardwood has the advantage of higher density and low lignin content which increases its pulp yield for a given volume of wood. Hardwood also provides better smoothness and opacity than softwood — qualities which are particularly important in printing papers. Finally, hardwoods have become more abundant and lower cost than softwoods. For all the above reasons, the industry has been increasing its use of hardwoods.

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A-1

3. Debarking and Chipping

Debarking is the first process step for all round-wood pulpwood as it enters the pulp mill. The two principal methods are steel drum and hydraulic debarking. The barking drum (a large open-ended steel drum about 10-12 feet in diameter and 40 feet long) is one of the oldest and still most popular methods. The drum rotates the logs slowly, and most of the work is done by the tumbling of logs against one another. Thus, the power requirement is minimized, but the drum debarkers have the disadvantage of roughing the log ends, causing dirt to become imbedded which in turn creates dirt problems in the pulping step.

Hydraulic barkers blast off the bark under a high-pressure water jet as the log is rotated. These are especially effective for barking the large coniferous logs found principally in the West. However, use of the technique is likely to diminish because of its high energy requirements, water pollution (bow-off which adds to the pulp mill effluent discharge, and because the process requires a relatively narrow range of tree diameters for optimum efficiency.

After debarking, the logs that are to be used for chemical and certain types of mechanical pulping are reduced to chips by a rotating knife device. Chipping improves the rate of cooking liquor penetration during chemical pulping and is also required for the refiner groundwood and thermomechanical pulping processes which will be described later. The added cost (mainly energy) of chipping is avoided if the mill uses residues from lumber and plywood mills which are generally provided in chip form. Sawdust residues from these mills can also be used as pulpwood for certain products.

Some thin barked wood species can be chipped with their bark on, and used in the dark-colored products produced by the kraft and NSSC processes. Similarly, some of the sawmill and plywood mill residues include a fairly high bark content which can be tolerated particularly in the kraft pulping process. Uniformity in chip size is important in chemical pulping. Therefore, before entering the process the chips are screened to separate those of desirable size from oversize material and sawdust. The oversize material is crushed and rescreened, and the sawdust, if it is not suitable for pulping, is normally used for fuel.

4. Mechanical Pulping

Mechanical pulping is the simplest method of producing wood pulp. It consists of two principal physical methods of producing groundwood pulps. In the older technology, stone grinding, logs are ground on large grind stones. The newer technology which is gaining rapid use is chip refining or refiner groundwood. The process converts pulp wood chips to groundwood pulp, using attrition mills consisting of counter-rotating metal shearing discs. Refiner groundwood is generally preferred over stone groundwood because it yields longer fibers and thus stronger paper. Another mechanical process, thermomechanical pulping, offers the potential of providing even stronger pulps than refiner groundwood; this will be discussed later under New Technology.

Virtually all groundwood pulp is produced from softwood raw materials: spruce in the Northeast, pine in the South and Douglas fir and hemlock on the West Coast. Aspen, a low-density hardwood, is used for relatively small amounts of groundwood production in the North Central region. Most groundwood is produced and consumed in integrated pulp/paper mills.

Compared with chemical pulping, groundwood pulping requires a higher net power consumption, and it provides a shorter pulp fiber owing to the considerable fiber damage caused by grinding. The pulp produces a relatively weak paper that discolors easily on exposure to light. On

the other hand, groundwood provides a much higher yield, converting some 95% of the wood into pulp, compared to about a 50% yield for the bleached kraft pulp process. Another noteworthy advantage of the groundwood process is that it produces virtually no on-site air pollution and generates much lower water pollution, owing to its higher pulp yield, than the chemical pulping processes.

Groundwood's strength problem is compensated for by blending long fiber chemical pulp prior to the paper making stage. Its short fiber length helps to provide a smooth printing surface for products like newsprint and uncoated groundwood printing papers, the two principal applications.

Table A-1 shows the regional and size distributions for the U.S. groundwood mills. The Northeast (primarily Maine) ranks second to the South in capacity; both regions provide an ample supply of softwood and relatively low cost electricity. It should be noted that these ingredients are also plentiful in Canada, which produces roughly twice the amount of groundwood pulp and paper as the United States. Most small groundwood mills are located in the Northeastern and North Central regions. These are engaged primarily in producing uncoated groundwood papers which bring a somewhat higher price and serve smaller, more specialized markets than newsprint. Newsprint is almost entirely produced by the larger mills, most of which also produce bleached kraft pulp and hence are included under the latter process category in this analysis.

5. Kraft Pulping

The kraft process represents the dominant pulping method in the United States in terms of production tonnage. One of its chief advantages is that it can be used to pulp the entire spectrum of wood species, including both the softwood and hardwood varieties. The process is commonly termed the sulfate process because sodium sulfate, traditionally has been used as a make-up chemical. The kraft process employs a water solution of sodium sulfide and sodium hydroxide to dissolve the lignin and pentosan sections of the wood while leaving the cellulose portion. Typically, over 85% of the lignin is removed; however, the cooking liquor also insolubilizes some of the cellulose from the wood. These losses contribute to a relatively low pulp yield. The cooking process takes place in high temperature batch or continuous reactor vessels, after which the pulp is separated from the cooking liquor and washed.

The waste liquor from the pulping step is fed to a kraft recovery furnace, which encompasses incineration of the dissolved organic chemicals and recovery and reconstitution of the sodium sulfide and sodium hydroxide, which are recycled to the pulping step. Incineration, recovery of chemicals and recycle to the process are an economic necessity in kraft pulping because of the high chemical loadings that are required. The incineration process, however, creates the significant air pollution and odor problems associated with the kraft mills. Pulp washing and particularly pulp bleaching, if it is included, also cause a sizable water pollution problem.

The objective of bleaching is to produce a whiter and brighter pulp stock by removing residual lignins and other dark colored residues in the pulp. Kraft pulp is relatively difficult to bleach. Bleaching involves a multistage process generally employing a series of chlorine, chlorine dioxide and sodium hypochlorite bleaching stages, each of which is followed by a caustic extraction step, after which the pulp is given a final wash.

TABLE A-1

GROUNDWOOD PROCESS[1] - REGIONAL DISTRIBUTION, 1975

No. of Mills

Size tpd	Northeast	No. Central	South	West	Total
30-100	2	3	0	1	6
101-350	7	5	1	3	16
351-800	1	-	-	-	1
Total	10	8	1	4	23
1974 % of Capacity Tonnage[2]	26.3	13.4	43.8	16.4	100.0

(1) Includes chemi-mechanical mills.

(2) Includes groundwood produced in multi-process mills (API, Paper, Paperboard, Wood pulp capacity, 1974-1977).

SOURCES:
- Lockwood's Directory of the Paper & Allied Trades, 1975.
- Industry Sources.

Kraft pulp is used in a wide variety of paper and paperboard products including linerboard, unbleached kraft packaging paper, printing and writing paper, tissue, bleached paperboard and as a blending pulp with groundwood to produce newsprint and uncoated groundwood paper.

Table A-2 shows the size and regional distribution of mills that produce only unbleached kraft pulp. All are integrated to the production of unbleached kraft paperboard (mainly linerboard) and/or unbleached kraft bag and sack papers. Unbleached kraft pulp mills which also produce bleached kraft pulp were placed under the bleached category in this study, since bleaching is the most serious cause of their water pollution problems. The table indicates a dominant concentration of unbleached kraft mills in the South. Considering that the distribution includes the largest mills, the total spread in mill sizes is relatively small. This pattern is caused by the fact that the kraft pulping is a relatively new process, having been initiated in this country in the 1930's, and that the process economics benefit importantly from large-scale operations.

Table A-3 shows a corresponding size distribution for bleached kraft pulp mills. The bleached pulp mill category includes "complex" mills that produce unbleached kraft pulp and other types of pulping, along with bleached kraft. The table indicates that these mills are somewhat smaller and are distributed more evenly than the unbleached kraft mills. A significant amount of bleached pulp production in the Northeast and North Central regions primarily reflects the production of hardwood pulp for tissue and printing papers and market pulp. With the exception of a few mills that produce market pulp exclusively, most of the bleached kraft pulp mills are integrated to on-site paper and paperboard production. Such products include: bleached paperboard, printing papers, tissue and newsprint.

6. Soda Pulping

Developed in 1851-1865, the soda process was the original method of chemically pulping wood. It derived its name from the use of caustic soda as the pulping reagent. The cost of the reagent made it necessary to recover and reuse the alkali in the residual liquor. It was subsequently found that the presence of sodium sulfide, in addition to caustic soda in the cooking liquor, allowed the pulping to proceed more rapidly and thus provide a less degraded pulp. This discovery led to the sulfate or kraft process and to a rapid decline in the use of the soda process.

Currently, only three U.S. mills are employing the soda process; they are located in New York, Tennessee, and Louisiana. The Louisiana mill pulps bagasse (sugar cane), while the other two mills use mainly hardwood pulpwood. All three mills produce printing and writing papers.

The soda process creates water pollution problems which are of about the same magnitude as that of the bleached kraft pulp process. Its air pollution problems, however, are significantly less because it requires no sulfur.

7. Sulfite Pulping

The acid sulfite process is also a relatively old one, having been discovered in 1874. It became the most important chemical pulping process, until being overtaken by the kraft process in 1917.

The original calcium base process involved burning sulfur to sulfur dioxide and reacting the gas with limestone (calcium carbonate) to form the cooking liquor. Batch digesters lined with acid-resistant brick are employed for the pulping, which is carried out under heat and pressure.

TABLE A-7

UNBLEACHED KRAFT PROCESS - REGIONAL DISTRIBUTION, 1973

(Mills Producing Unbleached Kraft Without Bleach Facilities)

No. of Mills

Size tpd	Northeast	No. Central	South	West	Total
200-499	-	-	4	1	5
500-999	-	-	12	1	13
1000-1399	-	-	5	1	6
1400-2000	-	-	4	-	4
			25	3	28
		% of Capacity Tonnage *			
	.3	1.2	81.5	17.1	100.0

* Includes unbleached kraft produced in multi-process mills. American Paper Institute Capacity Survey 1973-1976.

SOURCES: • Lockwood's Directory of the Paper & Allied Trades, 1975.
• Industry Sources.

TABLE A-1

BLEACHED KRAFT PROCESS - REGIONAL DISTRIBUTION 1975

Size tpd[1]	No. of Mills				
	Northeast	No. Central	South	West	Total
150-499	5	5	6	4	20
500-999	6	2	19	8	35
1000-1600	-	-	21	3	24
Total	11	7	46	15	79
	1974 - % of Capacity Tonnage (API, Paper, Paperboard, Wood Pulp Capacity 1974-1977)				
	10.7	6.1	68.9	14.3	100.0

[1]Total Kraft Pulp Capacity.

SOURCE:
- Lockwood's
- Industry Sources

Unbleached sulfite pulp, unlike other unbleached chemical pulps, has a relatively light color and can be bleached by comparatively simple two- or three-stage bleach methods. On the other hand, it produces a relatively weak pulp. Therefore, its chief applications are in bleached printing/writing papers, tissue, and dissolving pulp. Its cooking time, final temperature, and acid concentration are selected in relation to the final product. For example, dissolving pulp requires cooking out most of the hemicellulose content, and this adds to the cooking time as well as to the water effluent loadings.

The sulfite process' chemical requirements and costs are far lower than for the kraft process; hence sulfite liquors traditionally have been discarded without treatment. With the advent of pollution abatement regulations, however, most sulfite pulp mills have installed chemical recovery or incineration units to either recycle their pulping chemicals, generate energy, or both. Traditionally, relatively inexpensive calcium was the only cooking liquor base used; but recently, sodium, magnesium and ammonia-based liquors have been employed, particularly in North America and Scandinavia. These bases cost four to five times more per ton of pulp than calcium; but in addition to easier chemical recovery and reduced stream pollution, these also provide reduced cooking time, more marketable by-products, and greater brightness.

Currently, there are still 14 out of 60 U.S. sulfite mills that do not have chemical incineration or recovery units. Since installation of an incineration/recovery unit entails a large capital expenditure which may not be economically justifiable in the case of a small mill, mills without chemical recovery systems received special attention in the mill closure analysis. Four of the above fourteen mills use a substantial amount of their sulfite liquor to produce by-products such as road binders, or raw materials to produce vanilla, yeast, alcohol, insecticides and inks. By-product recovery both reduces their water pollution loadings and increases the revenue. However, there is an insufficient market for the by-products for all sulfite mills to reduce their water pollution problem in this manner.

Table A-4 shows the 1975 regional distribution of sulfite pulp mills. Two mills have closed since 1973. Capacity is split about evenly between the West and the East, but the average mill size is much smaller in the East.

8. NSSC Pulping

The neutral sulfite semichemical process combines a light chemical treatment — to achieve partial softening of the fibers — with mechanical refining to complete the fiberization. The process is used almost exclusively to convert hardwood pulpwood into a special high-yield pulp for the manufacture of corrugating medium, the fluting material in corrugated containers. Pulp yield is high, 65-80% of the pulpwood, since only part of the lignin is removed. The chemical pretreatment reduces the amount of power required in comparison to groundwood pulp and increases the average fiber length and thus the strength. The NSSC process also lends itself to use in relatively small mills, since it requires a lower capital investment for efficient operations than either a chemical or a groundwood pulp mill.

The pollution problems associated with NSSC pulping are similar to those of the sulfite process; however, they are not as extensive owing to the lower chemical concentrations. Traditionally, a sodium sulfite pulping base has been used, but this is gradually being displaced by ammonia and magnesium which can be more easily recovered. The sodium base has no economic recovery system, although it can be fed into the kraft recovery furnace at an adjacent kraft mill.

TABLE A-4

REGIONAL DISTRIBUTION OF SULFITE MILLS, 1975

(No. of Mills)

Size (tpd)	Northeast	North Central	South	West	Total
80-149	0	2	-	5	7
150-299	1	5	-	3	9
300-499	1	-	1	3	5
500-850	2	1	-	4	7
Total	4	8	1	15	28

SOURCES:
- Lockwood's Directory of the Paper & Allied Trades, 1975
- Industry Sources

In some cases, specially designed incineration systems are employed, producing an inert ash in substantial quantities which must be either sold or discarded. There are five NSSC mills that have no recovery or incineration systems or that are not tied into municipal treatment systems. These were given special attention in AID-2 closure screening analysis, because investment in chemical incineration and recovery systems requires substantial capital, which may not be justified if the mill is marginally profitable.

Tables A-5 and A-6 show the regional distribution of the NSSC pulp mills, all of which are integrated to the on-site production of corrugating medium. There is a relatively even geographical distribution compared with unbleached kraft pulp, owing to the availability of hardwood pulpwood throughout most parts of the country. As would be expected, the NSSC mills, combined with kraft mills, have a much larger total scale of operation and are primarily situated in the South and West, as is the kraft pulping industry. Regionally 46% of all NSSC pulp is produced in the South, 33% in the North Central region, 11% in the West, and 10% in the Northeast.

9. Pulp Deinking

Deinking processes are used to convert printed forms of wastepaper to a white pulp substitute. Printing papers, tissue and newsprint constitute the major applications for deinked pulp. Deinking is generally carried out through the use of chemical reagents such as soda ash liquor, lime, borax and a variety of others. Bleaching with chlorine and sodium hypochloride usually follows the deinking operation.

The water effluent loadings of deinking mills are quite high because of the discarded inks, lignin and chemical reagents. The effluent, however, can be handled by conventional primary and secondary treatment techniques; chemical recovery is not feasible.

Table A-7 shows the regional distribution of deinked pulp mills. It indicates that by far the heaviest concentration of these mills is in the Northeastern and North Central regions, where there are heavy concentrations of printing and converting plants which provide most of the wastepaper raw material for deinking. These mills provide a source of pulp (often supplemental) close to the principal market centers for printing and writing papers, tissue and newsprint.

10. Recycled Paperboard

Recycled paperboard, sometimes called combination paperboard, employs a variety of wastepaper grades which are generally mixed together to form the pulp furnish. These grades include old corrugated containers, newsprint, and mixed wastepaper grades. The paperboard is used in a variety of applications including corrugated containerboard, folding boxboard, gypsum wallboard liner and a variety of smaller volume products. The repulping process consists of heating the wastepaper in water, screening off foreign material such as tape and wire, and sometimes also incorporates an asphalt removal step.

The effluent loadings from a recycled paperboard operation are quite high because of the extraneous material introduced by the wastepaper and removed in the screening and cleaning operations. However, the nature of the product is such that it generally lends itself to a very high degree of water recycling, which reduces the water volumes that must be handled in the treatment plants.

TABLE A-5

REGIONAL DISTRIBUTION OF LSBC PROCESS, 1978

(No. of Mills)

Rivet Spd	Northeast	North Central	South	West	Total
100-200	1	2	3	1	7
201-450	1	7	4	-	12
451-700	1	2	1	-	4
TOTAL	3	11	8	1	23

SOURCE: Lockwood's Directory, 1975.

TABLE V-6

REGIONAL DISTRIBUTION OF COMBINED SORT-CRAFT PROCESS, 1975

(No. of Mills)

Rated Cpd	Northeast	North Central	South	West	Total
600-750	-	-	-	3	3
751-1500	1	-	5	2	8
1501-2250	-	-	6	1	7
2251-3000	-	-	1	-	1
TOTAL	1	-	12	6	19

SOURCE: Lockwood's Directory, 1975.

TABLE A-7

REGIONAL DISTRIBUTION OF DEINKED PULP MILLS, 1975

(No. of Mills)

Size (tpd)	Northeast	North Central	South	West	Total
20-99	6	7	1	1	15
100-399	7	5	-	4	16
400-800	2	3	-	-	5
Total	15	15	1	5	36

SOURCES:
- Lockwood's Directory 1975
- Industry Sources

Table A-8 shows the regional distribution of recycled paperboard mills. It shows that the heaviest concentration of mills are in the Northeast and North Central regions and that the majority of the very small mills are in the Northeast. The distribution of recycled paperboard capacity more or less follows the population distribution.

11. Nonintegrated Paper Mills

Nonintegrated paper mills consist of paper machine operations which exclusively purchase pulp produced at other locations to provide their fiber requirements. Thus, the only pulp-handling equipment prior to the refining and paper-making operations are repulping tanks to disintegrate the baled pulp. The nonintegrated mills primarily produce printing and writing papers, tissue papers and coarse papers, which include unbleached packaging paper and special industrial papers.

Water effluent loadings of the nonintegrated mills are relatively light since there is no on-site pulping, and the pulp that they purchase is in clean condition ready for paper making. The pollution loadings associated with the paper-making operation consist of pulp fines, plus chemical treatment and pigment losses during paper making. These can be handled by conventional wastewater treatment methods.

Tables A-9 and A-10 show the regional distribution of nonintegrated printing/writing and tissue mills. (Nonintegrated coarse paper mills including special industrial paper, wet machine board, and molded pulp were excluded from the analysis.) It indicates that by far the heaviest concentration of these mills are in the heavily populated Northeast and North Central regions where it has become uneconomical in many instances to produce pulp at the paper mill site. As is typical of other mill distributions, the smallest nonintegrated mills are in the Northeast.

12. Mill Closure Trends

Table A-11 shows the number of full mill closures and the capacity removed since 1960. An unprecedented number of closures occurred in 1970 and 1971 as the paper industry's profitability dropped to its lowest point since World War II.

By far the greatest number of closures have occurred in the recycled paperboard product sector. Both small (50 tons/day) and medium (100 tons/day) mills were affected, and the ownership was about equally divided between small and large firms. A combination of reasons led to the closures, including essentially static demand, high-cost mill sites in densely populated metropolitan areas, and obsolescence of the cylinder board process and its gradual replacement by forming devices such as the Ultraformer and Inverformer.

Printing and writing paper mills had the next largest closure incidence. Most of the closed mills were not integrated to pulp, which is indicative of the general cost/price squeeze caused by the narrowing gap between pulp and end-product prices. Closed mill owners were about equally divided between large and small firms.

The tissue mill closures were all nonintegrated mills that were owned by small companies. In addition to rising pulp prices, intense competition and increasing market share concentration on the part of the four leading producers contributed to the demise of these relatively small mills.

TABLE A-3

REGIONAL DISTRIBUTION OF NEWSPRINT PAPER BOARD MILLS, 1973

(No. of Mills)

Plant tpd	Northeast	North Central	South	West	Total
5-49	10	4	3	-	17
50-99	18	12	5	7	42
100-299	29	31	17	9	86
300-499	5	4	1	2	12
500-1000	1	2	-	-	3
Total	63	53	26	18	160
	==========	Percent of Capacity Tonnage[a]	==========		
	10.9	41.4	16.3	11.6	100.0

[a]Lockwood's Directory.

SOURCE: American Paper Institute Capacity Survey, 1973-1976.

TABLE A-9

REGIONAL DISTRIBUTION OF PRINTING, WRITING, AND RELATED PAPER MILLS, 1975

(Number of Mills)

Size: tpd	Northeast	North Central	South	West	Total
15-49	5	1	1	-	7
50-249	12	13	1	1	27
250-1000	2	5	-	1	8
TOTAL	19	19	2	2	42

SOURCES: • Lockwood's Directory, 1975.

• Industry Sources.

TABLE A-10

REGIONAL DISTRIBUTION OF NONINTEGRATED TISSUE MILLS, 1973

(Number of Mills)

Size: tpd	Northeast	North Central	South	West	Total
7-15	7	-	2	2	11
16-100	22	7	4	3	36
101-1000	4	4	3	1	12
TOTAL	33	11	9	6	59

SOURCES: • Lockwood's Directory, 1975.

• Industry Sources.

TABLE A-11

U. S. PAPER INDUSTRY MILL CLOSURES, 1963 - 1974
(No. Mills/Annual Capacity - Thousand Tons)

Year	Paper and Pulp Mill Closures: Recycled Paperboard	Printing & Writing	Tissue	Other	Additional Pulp Mill Closures
1965	2/51	IN/10			1/21 (ite)
1966	1/23	IN/14	IN/5	Kraft IN/13	
1967	3/87	2N/135	2N/15		1/34 (ite) 1/21 (GW) 1/21 (Soda)
1968	1/32				2/66 (ite) 2/21 (GW) 1/14 (SC)
1969	2/47	2N/14	2N/13	Kraft IN/53 Glassine IN/15	3/166 (ite) 3/178 (GW)
1970	8/279*	2N/17*	IN/8		3/95 (ite) 3/63 (GW) 1/40 (SC)
1971	5/180	4N,1I/238*	2N/13	Kraft IN/25 Spec. Ind. IN/6	3/78 (ite)
1972	5/219	IN,1I/65	2N/26*	Glassine IN/16	
1973		*	2N/24*	Constr. Paper 1/42	
1974	3/85	IN/40		Semi-Chem 1I/100 Spec. Ind. IN/5	
1975 thru June	4/ 197	2N/185			1/105(ite)
TOTALS	34/ 1200	16N,2I/719	12N/104	8N,1I/275	26/923

N = Nonintegrated to pulp
I = Integrated
Kraft = Mainly unbleached papers

Pulp Symbols = ite = sulfite
GW = groundwood
SC = semi-chemical

* Excludes partial closures, and mills sold and later reopened in same grades.

Source: American Paper Institute

Other product sectors which experienced closures include unbleached kraft, glassine papers, special industrial paper, corrugating medium, and construction paper. All but one of the nine affected mills were not integrated to pulp and were relatively small mills. The mill owners were about equally divided between small and large firms.

Pulp mill closures where the paper mills continued to operate as nonintegrated or partially integrated mills were only slightly less numerous than recycled paperboard mill closures. Sulfite mills experienced the highest closure rate, with fully 14 out of the total 20 pulp mill closures since 1965. All of these mills lacked the costly chemical recovery or incineration systems which were needed to meet state water pollution control requirements. Fourteen U.S. sulfite mills still remain that do not have recovery or incineration systems, presumably because they cannot be economically justified and/or their state requirements do not stipulate that level of control.

There were nine groundwood pulp mill closures since 1965. These were for the most part very small mills that utilized relatively high cost softwood pulpwood which made them uneconomical. ADL doubts that pollution had a significant bearing on these closures, since groundwood is the least polluting of the pulping processes.

The remaining pulp mill closures consisted of two semichemical (NSSC) mills and one soda pulp mill. These were probably pollution-related, since the processes cause significant water pollution loadings. In the case of the NSSC mill closures, the companies shifted to a wastepaper pulp furnish and continued to produce corrugating medium.

Methodical, accurate accountings have not been made concerning the cause of the above mill closures or what role, if any, pollution control regulations had in the closures. Many of the closures were undoubtedly the results solely of unfavorable economic conditions. Conversely, pollution-related closures were invariably due to the combination of unfavorable economics coupled with the need to reinvest substantial amounts of capital to correct pollution problems, and then incur a continuing higher operating cost. Therefore, the above closure trend analysis points to product and process sectors that traditionally have been most vulnerable to closures and which ADL analyzed in particular detail to assess the probability of future closures in which federal pollution control regulations are likely to be significant contributing factors.

APPENDIX B

CURRENT TECHNOLOGY CHANGES

Following is a brief discussion of pulping, bleaching and papermaking process changes which are either in the early stages of commercial development or in large-scale pilot plant operation and which have or might have a significant impact on the costs of meeting air/water pollution regulations, or on the economics of pulping or papermaking.

1. Pulping Systems

Oxygen Pulping - The kraft pulping system, by far the most important chemical pulping process, contributes appreciably to both air and water pollution. Because pollution arises partly as a result of the use of sulfur compounds used in the process, there is a high degree of interest in nonsulfur pulping processes. One of these approaching commercial status is oxygen pulping.

The major incentive for the use of oxygen pulping is a reduction in both air and water pollution levels; since there is no sulfur there are no malodorous organic sulfur compounds emanating from the system — either in air emissions or water effluent from the mill.

A second important incentive for the use of oxygen pulping comes from the potential elimination of the chlorination stage in the pulp bleaching system. This is important because the conventional chlorination and subsequent alkaline extraction stages contain large quantities of chlorine compounds and are difficult to recover and so pose a pollution problem. These first two stages would be replaced by oxygen pulping. The effluent from the oxygen treatment contains no chlorine and so can be recovered and recycled to the recovery furnace where the organic material is burned (energy recovery) and the inorganic material is recovered in the form of fresh pulping chemical. ADL calculations based on laboratory data indicate that capital and operating costs for kraft and oxygen pulping will be similar. With present technology oxygen pulp strength is lower than that of kraft. Thus, the major incentives for the use of oxygen pulping technology are its pollution abatement aspects.

The first commercial oxygen pulp mill in the world is being constructed by Weyerhaeuser at Everett, Washington. If pulp strength deficiencies can be corrected, the oxygen pulping process could gain a degree of acceptance as a substitute for the kraft process that provides a means of reducing both air and water pollution and treatment costs. Conversion of kraft to oxygen pulping would require a major capital investment.

Thermomechanical Pulp (TMP) - Mechanical pulp (used primarily in newsprint and other, lower cost printing papers) is conventionally made by grinding a log on a grindstone or by subjecting chips to mechanical disintegration in a double disk refiner. Recently, it has been discovered that a superior mechanical pulp can be made if the wood is steamed and then disintegrated under pressure. Yields are slightly lower than for the conventional systems — largely because of somewhat higher dissolved wood solvents, but pulp strength values are higher. Thus, it is usually possible to reduce the amount of blended chemical pulp needed to strengthen the paper.

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From a pollution point of view, there will be a greater problem with TMP because of the higher quantity of dissolved organic material in the mill effluent. Counterbalancing this is the possibility of using lower value residue wood chips and sawdust in the TMP process. These raw materials frequently constitute a pollution problem. In the past they have been burned or disposed of by leaving them in piles to disintegrate. Pollution problems have arisen from wood residues being washed into rivers, and other bodies of water, causing water contamination from leached degradation products of the wood residues and air pollution from burners.

The TMP process is in use in several mills in North America and Europe. In addition, a number of new installations are on order or being installed so a fairly rapid adoption rate is indicated.

Polysulfide Pulping with Kraft. The normal kraft pulp yield of 42-45% can be increased to as much as 49-50% (i.e., a 10% increase) if polysulfide is added to the conventional kraft cooking liquor. This advantage is particularly important in high wood cost areas. The process was developed in Norway and is being used in two or three Scandinavian mills. The extra sulfur used in the system cannot be recovered and so has to be vented to the atmosphere. The result is a significant increase in the air pollution load at the mills using polysulfide pulping.

Recently the Mead Corp. in the United States has developed a recovery system for polysulfide and has installed a commercial unit at their Chillicothe Mill. They are obtaining a significant yield increase with no appreciable increase in the air pollution load. Mead Corp. is actively seeking licensees for their patented recovery process. In areas with very high wood costs, the use of polysulfide pulping and recovery could prove to be attractive.

Kraft-Hydrogen Sulfide Pretreatment. When wood chips are pretreated with hydrogen sulfide, followed by a conventional kraft cooking liquor, a yield increase is obtained similar to, or higher than, that from polysulfide pulping. MacMillan Bloedel in Vancouver, British Columbia, has developed a recovery system for hydrogen sulfide pretreatment and has extensive experience with a large pilot plant in their Nanaimo, B.C. mill.

MacMillan Bloedel is also actively seeking licensees for their patented pulping process. This process is expected to have the same degree of applicability as polysulfide pulping systems.

Nonsulfur Semi-Chemical Pulping. Most of the corrugating medium in the United States is made with the so-called neutral sulfite semi-chemical process (NSSC). Until recently in many mills it was the practice to simply discard the effluent from this pulping process to the river, sewer, etc.

A variety of NSSC chemical recovery processes have been developed and many have obtained commercial acceptance. Most of the recovery systems go through a sulfide phase in a recovery furnace (including so-called cross recovery or use of NSSC liquor for make-up chemicals in a kraft recovery furnace) and so contribute significantly to air pollution.

Two U.S. companies, Westvaco and Owens-Illinois, have, independently, developed and patented nonsulfur semi-chemical pulping processes. Both companies have made one commercial installation in the United States. The process details have not been revealed by either company. Both, however, are actively seeking licensees of their process.

Green Liquor Semi-Chemical Pulping. It has been found recently that a satisfactory semi-chemical pulp can be made with kraft green liquor as a cooking chemical rather than neutral sulfite liquor. The kraft green liquor is simply a solution of recovered kraft chemicals which have not been subjected to the final recovery step (i.e., conversion of carbonate to hydroxide). The advantage is that the effluent from the pulping process can be recovered in conventional kraft systems. This is true also of the cross recovery of NSSC liquors with kraft recovery system but this approach is limited by the quantity of make-up chemical required in the kraft system. When NSSC liquor is used as a source of make-up chemicals, the ratio of kraft with NSSC pulping production allowed in cross recovery is about 4 kraft to 1 NSSC. As an added factor in recent years the more strict control of atmospheric pollution from kraft mills has limited the quantity of NSSC liquor which can be used as make-up chemical. With kraft green liquor semi-chemical pulping, there is no limit on the production of semi-chemical pulping integrated to a kraft pulping and recovery unit.

A number of NSSC mills in the United States have been converted to kraft green liquor and ADL expects the trend to continue.

2. Chemical Recovery

SCA-Billerud Recovery for NSSC. One of the most recent new, large, NSSC mills constructed (Mead Corp.'s 800 ton/day mill in Alabama) is being built with still another modification of NSSC recovery — the SCA-Billerud System. In this process the recovered organic material from NSSC pulping is heated at elevated temperatures under conditions such that one of the active pulping chemicals, sulfur dioxide, as well as heat and sodium values, are recovered directly from the recovery furnace. Sulfides are not handled outside of the recovery units and so the development of noxious sulfur compounds is lessened. There are several such installations in Europe but Mead's is the first in the United States.

Sunoco Recovery of NSSC Pulping Liquors. Sunoco Products Company in Hartsville, South Carolina has recently announced yet another sulfite recovery system. Theirs utilizes the fact that certain silicate and aluminate salts are strongly acidic at the temperatures encountered in a recovery furnace and are highly insoluble in relatively dilute water solutions. Thus, the NSSC pulp digestor effluent is combined with the silicate-aluminate salt prior to its combustion in the recovery furnace. Sulfur dioxide is recovered directly from the furnace and sodium values are recovered when the smelt from the recovery furnace is dissolved in water and silicate-aluminate compounds precipitate. These precipitated salts are recovered and recycled.

Sunoco is offering to license the process to interested parties. The advantage of the Sunoco system from the standpoint of pollution abatement lies in the recovery of sulfur dioxide directly without going through the sulfide stage. To date the only installation is the Sunoco one although they are said to be negotiating with several interested pulp mills.

Variations in Kraft Make-Up Chemicals. When kraft mills are forced to close up their systems and retain more of their sulfur values, the use of salt cake as a make-up chemical becomes increasingly difficult because it provides an excess of sulfur beyond that required by the chemistry of the pulping reaction. In addition, unwanted sulfur values are added to the system when effluents from the tall oil recovery system and chlorine dioxide generators are added to the kraft furnace. This has led to the substitution of caustic soda and sulfur for salt cake and other sodium-sulfur make-up chemicals in many kraft systems. Although the cost of the caustic is

somewhat higher than the salt cake, the emission of objectionable sulfur compounds from the recovery process is considerably lessened. There already has been rapid displacement of salt cake in kraft pulping. ADL expects that the trend towards the use of caustic in place of salt cake will continue.

3. Bleaching

Oxygen. Oxygen is being used commercially in pulp bleaching as a substitute for the chlorination and extraction stages of a conventional kraft bleaching sequence. The advantages and results from the standpoint of pollution are similar to those experienced with oxygen pulping. The comparative economics of oxygen and conventional bleaching are similar. Thus, the major incentive for oxygen pulping is pollution abatement. Because oxygen pulp strength is sometimes lower than kraft, ADL expects that commercial use of the process will be limited unless process changes result in pulp strength improvements.

Replacement of Chlorine with Chlorine Dioxide. Kraft pulp bleaching is conventionally carried out in four to six stages. A typical sequence would be chlorination followed by alkaline extraction, chlorine dioxide, alkaline extraction and chlorine dioxide. The effluents from the first two stages (chlorination and alkaline extraction) contain substantial quantities of inorganic and organic chlorine compounds as well as nonchlorinated organics. Thus, these two effluent streams constitute a major pollution problem for the bleached kraft industry.

It has been found that if chlorine dioxide is added along with chlorine in the first stage or if dioxide is added in an initial stage followed by chlorination, the quantity of chlorine consumed can be reduced. The quantity of chlorine which can be eliminated is directly related to the quantity of chlorine dioxide used. In principle, it is possible to substitute all of the chlorine with chlorine dioxide but present economics permit only a partial substitution. Chlorine dioxide has a much greater oxidizing power per chlorine atom than chlorine and in addition the mechanism of the chlorine dioxide action is such that chlorinated organics are not produced to the same degree as with chlorine. Thus, the effluent from a chlorine dioxide stage is much less offensive than from a chlorination stage. There has been a significant trend to replacement of chlorine with chlorine dioxide and ADL expects this to continue.

Displacement Bleaching and Washing. One of the reasons the bleach plant effluent is so difficult to handle from a pollution point of view is the high dilution of the dissolved organics and inorganics. The high dilution arises from the need to add large quantities of water to the pulp after each bleaching stage. A recent development by the Swedish firm, Kamyr, gives a promise of enabling the bleach plant operator to use less water and discharge a considerably more concentrated effluent. In the Kamyr development the pulp is washed by displacement rather than by dilution as in the conventional processing step. A number of these displacement washers are in commercial operation in bleach plants.

As an added refinement of the Kamyr diffusion washing, a 150-ton-per-day pilot bleach plant is operating in Finland with bleached chemicals as well as water being added in the diffusion washers. The pilot plant has three stages of bleaching with washing between each stage carried out in a single tower. Indications are that a substantial reduction of water usage as well as higher concentration of dissolved solids in the mill effluent has been achieved. At least one commercial unit is being constructed in the United States based on the three-stage bleach, single tower principle.

High Consistency — Gas Phase Bleaching. Similar reductions in water consumption and an increase in dissolved solids concentration in the mill bleach effluent can be achieved with a high consistency press and gas phase bleaching at high consistencies. This concept has been developed at Paprican Laboratories in Montreal in cooperation with Impco Ingersol Rand. An Impco press is used which enables the bleach plant operator to press the pulp to a solids content of 35-40%. A bleaching chemical such as chlorine is then applied in the gas phase. After the reaction has taken place the pulp is dilution washed by adding water to bring the pulp slurry to a 10% solids level and then repressing to the 35-40% solids level. Weyerhaeuser is operating a single stage pilot plant on this principle. Results of the pilot plant operation have not yet been made public.

4. Water Reuse

Most, if not all, pulp and paper mills have effected a substantial reduction in water consumption, or increase in water reuse, in the past several years. The pressures and constraints on water reuse are largely social and economic in origin rather than technical. The engineering and chemical techniques for increased recycle of water within a pulp mill, bleach plant or paper mill are readily available.

In the early days of the industry when water was extremely cheap and there was little concern over water pollution, the mills made little effort to achieve a high water recycle ratio. With increasing pressure to achieve reduction in water pollution, the mills have applied the available techniques to increase water reuse so as to decrease the hydraulic load on pollution abatement facilities and thus decrease capital and operating costs.

One of the major constraints of water reuse is the market-oriented factor of consumer acceptance. High brightness levels and dirt specifications require a certain amount of water to be rejected from the system as a purge. The quantity of purged water could be reduced with less stringent consumer expectations as to brightness, dirt and other factors. Total recovery processes for the purged water (e.g., distillation, reverse osmosis, ion exchange, etc.) become prohibitively expensive.

However, more stringent effluent control regulations will cause a continuing decrease in the net quantity of water used in pulp and paper mills through application of presently available technology.

6. Papermaking

High Consistency Forming. In a conventional papermaking operation the pulp fiber is suspended in a large quantity of water prior to formation into a continuous fibrous web. As much as 1,000 lbs of water per lb of pulp is used. Recent developments have given promise of making it possible to substantially reduce the consumption of water in the papermaking and thus reduce the volume of effluent from the paper machine.

The Swedish Cellulose Research Institute in Stockholm and the Lodding Co. of the United States have developed paper machine modifications which would reduce the water used in suspending the fibers prior to forming to 25-50 pounds per pound of pulp. The Swedish development has been licensed to Ahlstrom in Finland and this company is installing equipment on a commercial machine. The Lodding equipment has been installed on North American paper machines with varying degrees of success. The major problem with both devices appears to be paper quality — especially uniformity of formation. Broad commercial use of these high consistency forming developments is probably several years away.

Dry Forming. Water effluent from papermaking operations could be eliminated completely if air instead of water were used to convey the fibers prior to formation of the web. There are several commercial examples of dry forming of paper — largely in the high-value specialty paper field. Honshu Paper Co. in Japan is making cigarette filter sheets, automotive air filters and household wipes in their patented dry forming process. A number of U.S. companies are making absorbent sheets for disposable diapers in dry forming operations. Karl Kroyer in Denmark has a semi-commercial dry forming unit making sanitary tissues. In England, St. Anne's board has installed a commercial dry forming board machine for the manufacture of recycled linerboard. At the last report this machine was still operating on an experimental basis.

The major impact on water pollution would come if dry forming were applicable to commodity grades of paper such as toilet tissues, linerboard, printing papers, newsprint, etc. As yet, it has not been possible to reproduce economically the paper qualities found with the commercial wet forming process with a dry forming operation. ADL expects that the development of dry forming for commodity grades is still a number of years away.

6. Wastepaper

Recovery from Municipal Trash. About 20% of the pulp and paper discarded in the United States is recovered and recycled to pulp and paper manufacturing. Further additional quantities could be collected if the demand was there, and if the collection systems were established with more emphasis on source separation or isolation of the discarded paper and paperboard. However, a large portion of the discarded paper and paperboard is not recoverable because it is co-mingled with garbage, tin cans, bottles, plastic, as well as other nonfibrous materials, and so cannot be recovered with conventional techniques.

There are a number of development programs aimed at recovery of usable fiber from municipal trash. One of these processes developed by Black Clawson has been subject to extensive pilot plant and semi-commercial trials. In this wet process the entire municipal trash is slurried in water and the fibers separated in a series of screening and washing steps. The recovered "garbage pulp" is at the low value end of the quality scale and can be used only in such products as roofing felt. The sponsors of the project now agree that with the present economics the most practical use for the recovered fiber is as a feedstock to a burner for heat recovery.

A dry separation approach has been explored by the Forest Products Laboratory and others. The entire municipal trash is reduced to uniform particle size and then the various components separated by a series of screens, cyclones and air fractionation steps. The Forest Products Laboratory representatives suggest that the recovered fiber be best utilized as a raw material for a reconstituted, resin bonded construction board product. The economics for this process apparently are not yet favorable in comparison with solid wood or reconstituted wood products.

APPENDIX C

CRITERIA FOR ASSIGNING MILLS TO PROCESS/PRODUCT SECTORS

1. Multiple Pulp Mills

Entire complex (including paper and paperboard mills) assigned to highest polluting component, i.e.:

- chemical plus mechanical pulp mills — assigned to chemical
- chemical plus deinked pulp mills — assigned to chemical
- deinked plus mechanical pulp mills — assigned to deinked
- sulfite plus unbleached kraft pulp mills — assigned to sulfite
- sulfite without chemical recovery plus bleached kraft pulp mills — assigned to sulfite
- sulfite with full chemical recovery plus bleached kraft — assigned to bleached kraft
- unbleached kraft and NSSC pulp mills — assigned to combined kraft/NSSC
- bleached kraft plus NSSC pulp mills — assigned to bleached kraft

2. Single Pulp Mills

Entire complex (including paper and superbond mills) assigned as follows:

- 100% bleached or unbleached kraft pulp mills — assigned to appropriate process category
- kraft mills producing both bleached and unbleached pulp (regardless of ratio) — assigned to bleached kraft
- sulfite mills (bleached and/or unbleached) — assigned to sulfite
- semi-chemical and deinked mills — assigned to appropriate process category
- chemi-mechanical mills — assigned to groundwood
- refiner and stone groundwood mills — assigned to groundwood
- cotton fiber (rag) pulp mills and their paper mills *excluded* from the study
- groundwood mills producing molded pulp products *excluded* from the study
- defibrated pulp mills were *not* considered as a pulp category

3. Nonintegrated Paper and Paperboard Mills

- *Note:* treated as integrated: paper and paperboard mills (including those listed separately in directories) that are connected by pipeline to a pulp mill even if the mills are owned by separate companies.
- Single product — assigned to appropriate nonintegrated product category
- multi product
  - single mill — assigned to highest tonnage product category
  - multi mill — treated as separate entities when available information indicated that these are physically separated although located in the same community.

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APPENDIX D

SUPPORTING DATA FOR ECONOMETRIC ANALYSIS

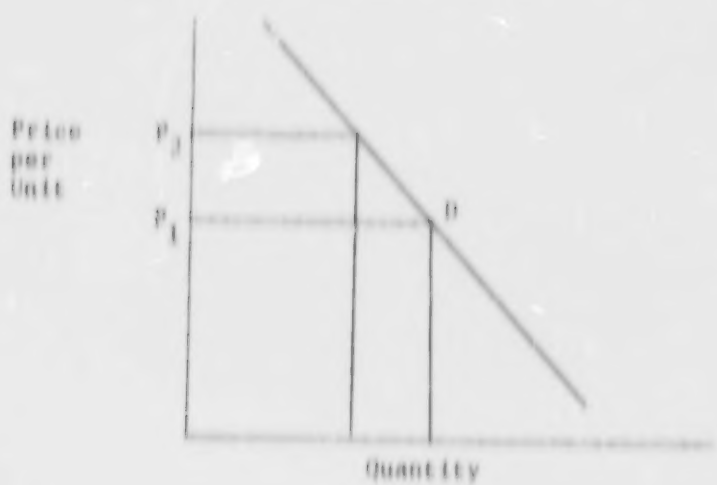
1. DETERMINANTS OF SUPPLY AND DEMAND

a. Product Demand

The theory of consumer behavior states that consumers as a group will purchase more of a product at a lower price than at a high price, due to the diminishing marginal utility associated with additional units of a product. The demand schedule of quantity purchased at different levels of prices is downward sloping, as shown in Figure D-1.

FIGURE D-1

DEMAND SCHEDULE



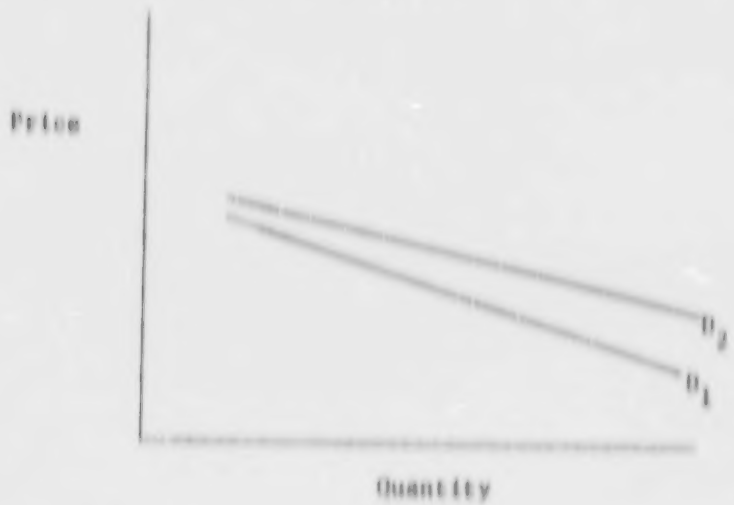
At price, P_1, quantity Q_1, is demanded. If the price increases to P_2, the quantity demanded falls to Q_2. The ratio of the percentage decline in quantity demanded to the percentage change in price is the price elasticity of demand:[1]

$$\epsilon = \frac{\Delta Q}{\frac{Q_1 + Q_2}{2}} \div \frac{\Delta P}{\frac{P_1 + P_2}{2}}$$

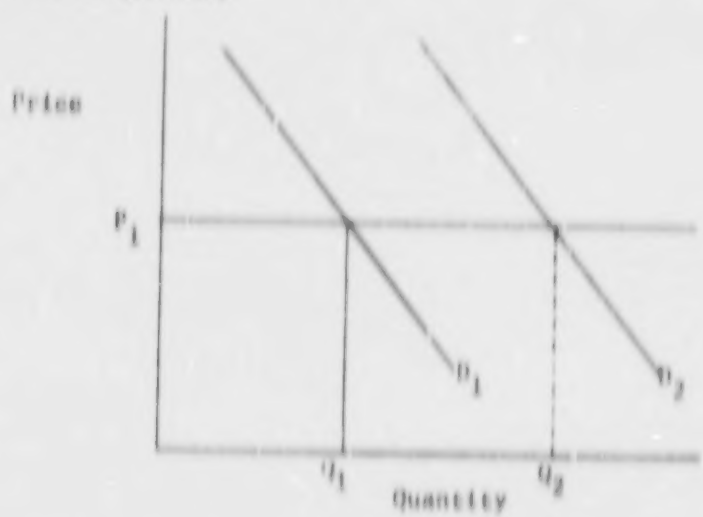
1. If the demand curve were logarithmic or of constant elasticity, the formula for elasticity of demand can be represented as $\frac{\Delta Q}{\Delta P} \times \frac{P}{Q}$

Pages 49, 50 and 51 are blank.

The degree of elasticity depends upon the availability of substitute products and the relative necessity of that product. If the number or nature of substitute products changes over time, the slope of the demand curve can change. The long-run response to large shifts in price may be quite different from the short-run response:



Increases in income shift the demand schedule for a normal good. As income increases, the demand curve shifts to the right, meaning that consumers will demand more of a good at the same price as they had previously:



The quantity of a product demanded depends upon the price of that product (p_i), the price of substitute products (p_s) and income (y):

$$Q = \phi_i (p_i, p_s, y) \qquad (1.0)$$

b. Product Supply

The theory of the firm postulates that an entrepreneur will purchase inputs and produce commodities for sale in such a fashion as to maximize profit on the sale of the good. The production function of the firm defines the relationship between the quantity produced and the quantity of variable inputs used in the production of goods. For example, for a firm using only two variable inputs,

$$Q = F(s_1, s_2) \tag{2.0}$$

where Q = quantity produced
s_1 = variable input 1
s_2 = variable input 2

The total cost of production is the sum of the unit variable costs plus the fixed costs that must be incurred regardless of the level of output. Marginal cost is the change in total cost which occurs due to a unit change in output.

$$C = r_1 s_1 + r_2 s_2 + f_c \tag{3.0}$$

or (total cost)

$$C = \phi_1(q) + f_c \tag{3.1}$$

where C = total cost of production
r_1 = price of variable input s_1
r_2 = price of variable input s_2
f_c = fixed cost

$$MC = \phi_1'(q) \quad \text{Marginal Cost} \tag{3.2}$$

$$AVC = \phi_1(q)/q \quad \text{Average Variable Cost} \tag{3.3}$$

During the short run, the entrepreneur can maximize profits by producing goods until marginal cost equals marginal revenue (which equals market price under perfect competition). The short-run supply curve of a competitive firm will then be the portion of the short-run marginal cost curve which lies above or on the average variable cost curve. The industry supply curve is the sum of the supply curves for the individual firms. Both for the industry and for the individual firm, the cost of producing additional units of output increases as quantity produced nears capacity.

In the paper industry, mills generally operate 24 hours per day, seven days per week. In the short run, the capacity constraint is relatively rigid; there is a point beyond which no additional amount of factor inputs will produce additional output. A graphic representation of marginal cost and average variable cost curves for this industry, and the resulting supply curve are as shown in Figure D-2 and D-3.

FIGURE D-2

MARGINAL COST AND AVERAGE COST

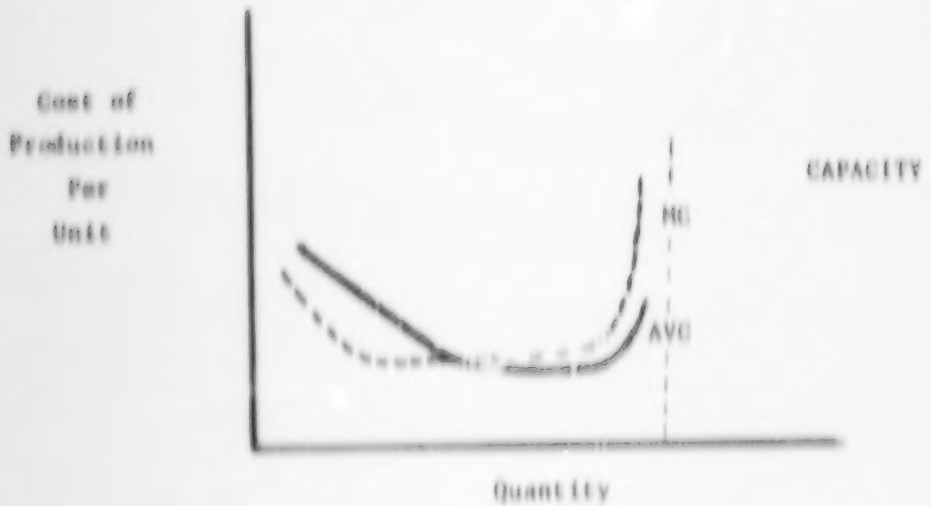
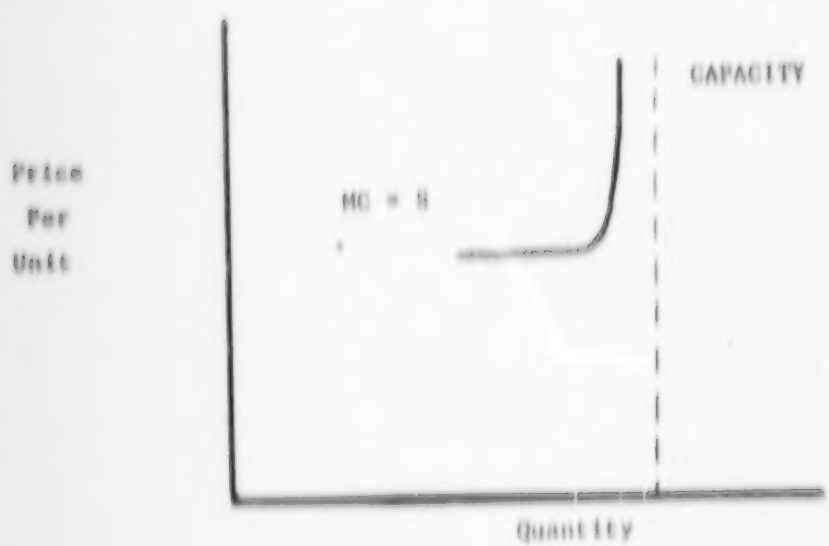


FIGURE D-3

SUPPLY CURVE



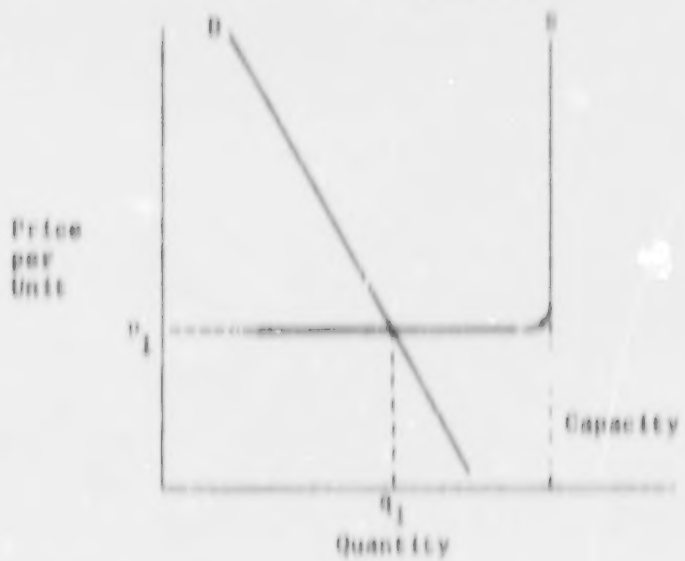
During the long run, capacity can enter and leave the industry and therefore all inputs are variable. The entrepreneur seeks to maximise profits in the long run by equating long-run marginal cost with marginal revenue. The long-run supply function is that portion of its *long-run marginal cost* function which exceeds its average cost curve. In the long-run, average cost includes "normal" profit, i.e., a rate of return commensurate with risk.

c. Market Equilibrium

At a given point in time the equilibrium market price for a good is determined by the intersection of the demand and supply schedules, as shown in Figure D-4. At price, P_1, the quantity demanded is q_1. Any increase in price (shift in the supply curve) will result in a lower quantity demanded.

FIGURE D-4

INTERSECTION



d. Effect of Pollution Controls

Because the installation of pollution control equipment is legislatively mandated, the economic decision to install it falls outside the purview of usual capital budgeting theory, and it is useful to consider the attendant operating costs as tantamount to a tax. The cost will have two components:

- A fixed component which does not vary with plant output; and
- A variable component, which alters the plant's marginal cost function.

The first component is equivalent to a tax on fixed assets; the second is equivalent to a unit tax on output. The mill's total cost function (3.0) becomes:

$$C = \theta_1 f(q) + t_1 q + t_2 f_c \qquad (4.0)$$

where t_1 = the increase in variable cost due to pollution control requirements

t_2 = the increase in fixed cost due to pollution control requirements

The mill's average variable cost and marginal cost function (4.3) become

$$AVC = \frac{\theta_1 f(q) + t_1 q}{q} \qquad (4.1)$$

$$MC = \theta_1 f(q) + t_1 \qquad (4.2)$$

and the short-run supply curve shifts upward by the amount t_1.

While a necessary condition to stay in operation is that price equal to or exceeding average variable cost, the mill owner must also perceive that he will recover the investment in the pollution capital equipment over the remaining life of the mill (i.e., the present value of expected future net cash flow must exceed the present salvage value of the mill). Therefore, the predominant effect of 1977 standards upon the industry supply curve is produced by plant closings, with the balance of the short-run effect reflecting the shift in the supply curve due to increase in operating costs from pollution control requirements.

In the long run, new plants will not be constructed unless owners are able to recover their investment plus a normal rate of return on the capital employed. Prices must be sufficient to recover the cost of compliance with environmental regulations. For this reason, the long-run price effects of environmental regulations were estimated by solving for the price necessary to earn a normal rate of return on a new mill:

- with the studied environmental regulations
- without the studied environmental regulations.

2. ECONOMETRIC MODELS

a. Formulation of Models

To identify the potential impacts of Federal pollution control requirements, the economic relationships described so far were combined into a model which includes:

- Industry supply functions
- Market demand functions.

ADL also explored the use of capacity growth functions. Capacity brought on-stream in a given year was related to capacity utilization three and four years previously (the length of time required to construct a pulp or paper mill during 1967-75).[2] Interest rates prevailing during the

2 This ranges from four to six years today.

construction period, pollution control expenditures as a percentage of total expenditures, general economic conditions and the wholesale price index for machinery were all included as lagged variables. (A sample equation is included in Section II-10.) However, the resulting equations were not sufficiently reliable to be useful.

Therefore, an alternative method of projecting capacity was used. Basically it employed a simple extrapolation of managements' expansion plans through 1979 as compiled and published annually by the API. Due to the long lead times required for new capacity, the industry knows within reasonable limits the new capacity expected to come on-stream three years hence (green-field, as well as incremental expansion). The 1970-1979 capacity growth rates for each product sector were projected taking into account product sector market and profitability trends, and the Chase general economic projections. Units of capacity rather than dollars of investment expenditure were employed because of the high rate of relative inflation in the cost of construction of new facilities in the 1970's. Units were then converted to capital based on the cost of constructing new facilities in 1975 estimated from the new mill process economic models.

Demand equations and supply equations were specified for many of the product sectors studied in this report. The demand equation included a macro-economic variable to represent the income effect, the transaction price of the product and for those sectors with substitute products (bleached board and unbleached kraft paper), the price of the predominant plastic substitute, which was incorporated in the form of a ratio to the price of the product. Due to the fact that the price of substitute products has moved with the prices of paper goods in the studied period (multi-colinearity) and perhaps the use of aggregate product group price data, the elasticity of substitution could not be measured for these products.

For some of the product sectors and for the industry aggregate equation, the specified supply equation did not explain a large percentage of the movement in prices. Prices of paper products correlated best with the price of energy. For many of the low-valued product sectors, capacity utilization rates were inversely related with price — a statistical oddity rather than a real phenomenon.

b. Statistical Technique

In product sectors where variable cost explained price movements in a consistent fashion, the two-stage least squares statistical technique was used to estimate the parameters of the demand equation. In other sectors, ordinary least squares, with a lagged price term, was used to estimate the parameters of the demand equation. The equations for the individual product sectors are part of Volume II, while equations for the aggregate of all paper and paperboard are at the end of this Appendix.

c. Error in Variables

The product sector groupings used in this report were based upon similarity of process and market. In aggregating across products in a product group, some of the effects may have been obscured. Also, on the supply side, wood, labor and energy prices were paper industry aggregates and not specific to individual products.

Although an effort was made to use consistent data throughout the historic period, changes in the base capacity and products classified in one grade versus another may have introduced error to the data base.

d. Aggregate Model Equations

The economic equations for the aggregate of paper and paperboard appear on the following pages. They represent the demand equation actually used in the analysis plus attempts to measure other relationships.

Equation 1: Aggregate Paper and Paperboard Consumption

This equation was developed using data from 1968 to 1975 and is the basis of the aggregate demand forecast and estimated price elasticity of demand. As such, the intermediate-term price impacts estimated with the funds flow model are also dependent upon the demand level and price elasticity forecast from this equation.

The statistics describing the equation are all statistically significant, except the coefficient of the wage-price freeze dummy variable. The standard error of 1.08% results in a two standard deviation error boundary of 2.6%.

Equation 2: Aggregate Paper and Paperboard Demand (1974)

This equation was developed using older data than Equation 1 and does not include 1975 data. This equation was not used in the analysis but was included to demonstrate that the parameters of the underlying demand for paper appear to be changing. The coefficients of the variables are not statistically different from Equation 1, but the coefficient of price is in the borderline.

Equation 3: Aggregate Paper and Paperboard Supply Equation (1974)

This supply equation, developed on data through 1974, indicates a relationship between price and capacity utilization such that price increases sharply as capacity utilization increases above practical maximum levels. When 1975 data is included, the coefficient changes sign — i.e., the price is inversely related to capacity utilization.

Equation 4: Change in Capacity

An equation was specified with this year's growth in paper industry capacity described as a function of economic growth in the recent past, capacity utilization (idle capacity) in the past and the cost of capital, weighted according to the paper industry construction profile (20% in year one, 40% in each of years two and three). The cost of capital equipment and the portion of total investment in pollution control equipment were statistically non-significant.

The standard error of 30.9% associated with this equation would result in a two standard-deviation range of 60.6%. When the equation was applied, it produced forecasts that were not as responsive to capacity utilization extremes — high or low — as are reasonable. For example, when capacity utilization was at or above 100%, the projected new capacity three years downstream was insufficient to fill the capacity shortage gap. The probable reason for this is that extremely high or low operating rates were not present in the development period. (The capacity tightness of 1974 would not result in new capacity on stream until 1977 in that model framework.) The model could not reflect structural changes that are occurring, for example, the longer lead time required to add capacity due to environmental impact statements, etc. The model was also insensitive to pollution control expenditures. In short, the mathematical equation was not likely to provide reasonable estimates of future capacity expansion, and therefore, it was not used.

9. LIMITATIONS OF ECONOMETRIC ANALYSIS

The econometric equations were used to estimate future demand for paper products (through 1983) and the reduction in demand that will occur as a result of price increases. Based upon the differences between Equation 1 and Equation 2, the underlying structure of the demand for paper products could still be changing; the full effects of the price increases of 1973-74 may not be yet fully reflected in the marketplace. The impact of this is that the forecast demand levels may be too high.

An upper and lower boundary forecast was made to indicate the expected variation from the forecast due to the equation. Additional differences from the forecast can arise from changes in the underlying demand structure for paper and paperboard and errors in the Chase Econometric forecast.

Equation 1: Aggregate Paper and Paperboard Consumption

CONSUMPTION = Constant (b$_0$) Mkt. Price$_{t-1}$ (b$_1$) IIP$_{t-1}$ (b$_2$) WPFRZ

Variable	Coefficient	t
C	11019.4	6.58
Mkt. Price$_{t-1}$	-54.42	4.08
IIP$_{t-1}$	97.53	8.73
Wage Price Freeze Dummy Variable	478.6	1.63

R^2 = .88 Standard Error: 3.32

DW = 2.27 Mean Y = 14863

F (3,32) = 76 Timeframe: 1968-1975

Method: Ordinary Least Squares

(1968)

61

Equation 1: Aggregate Paper and Paperboard (1974)

DEMAND EQUATION

$$\text{CONSUMPTION} = 9478.65 - 28.4852\,\widehat{\text{Market Price}} + 91.1316\,\text{IP}_{t-1} + 1014.34\,\text{WAGE PRICE FREEZE}$$

Right Hand Variable	Estimated Coefficient	t Statistic
Constant	9478.65	5.69886
$\widehat{\text{Market Price}}$	−28.4852	−3.10989
Index of Industrial Production$_{t-1}$	91.1316	20.3358
Wage Price Freeze	1014.34	5.58314

$R^2 = .9584$ Standard Error = 313

Durbin Watson = 1.6130 Mean Value of Y = 13728.4

F Statistic (3,48) = 368.7

Time Period = 1962-1974

Method = Two-Stage Least Squares

IDENTITIES

1. Consumption = Production − Exports + $\widehat{\text{Imports}}$
2. Market Price = [(Production − Exports) x Price + (Import Price x Imports)] ÷ Consumption

Equation 5: Aggregate Paper and Paperboard (1974)

SUPPLY EQUATION:

$$P_{PAB} = +4.05357\,(ENERGY + LABOR\ COST) + 1.23264\,WOOD\ PRICE - 6.08091\,WAGE\ PRICE\ FREEZE + .158084\,[1/C/\ IDLE\ CAPACITY \times 10^{3}]^{a}$$

Right Hand Variable	Estimated Coefficient	T Statistic
ENERGY + LABOR	4.05357	16.6683
WOOD PRICE	1.23264	3.46237
WPI	-6.08991	2.80233
[1/C/ IDLE CAPACITY $\times 10^{3}$]^{a}	.158084	2.515833

R^2 = .6980 — Standard Error = 3.25

Durbin Watson (Adj. for 0 gaps) = 1.0917 — Mean of Y = 142.883

F Statistic (4,44) = Not available for equations with no constant term

Time Period: 1962:1974, quarterly

Method: Ordinary Least Squares

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a/ IDLE CAPACITY = QUANTITY/CAPACITY

Equation 4: Aggregate Paper and Paperboard (1974)

CHANGE IN CAPACITY EQUATION:

$$\text{Change in Capacity} = 2603.67 + 13.9470\,(GNP_t - GNP_{t-1}) - 5578.92\,(\%\ \text{IDLE CAPACITY}_{t-1} + \%\ \text{IDLE CAPACITY}_{t-2}) - 76.9781\ \text{WEIGHTED COST OF CAPITAL}$$

Right Hand Variable	Estimated Coefficient	T Statistic
Constant	2603.67	4.0555
$GNP_t - GNP_{t-1}$	13.9470	4.44841
(% IDLE CAPACITY$_{t-1}$ + % IDLE CAPACITY$_{t-2}$)	-5578.92	-1.14943
WEIGHTED COST OF CAPITAL	- 76.9781	4.39168

R^2 = .470 Standard Error = 30.91

Durbin Watson = 6393

F Statistic (3,44) = 14.1917

Method: Ordinary Least Squares

APPENDIX E

SUPPORTING DATA FOR COSTS OF COMPLIANCE

This appendix contains supporting data for deriving the cost of complying with the studied air, water, and noise regulations. It presents the regulations on which the cost estimates are based and describes the methodology used in the calculations.

Because certain factors and assumptions are common to all three types of regulations, a brief generalized approach and summary of the common cost bases/assumptions used in the analysis are presented below. The studied regulations (for air, water, and noise) are discussed separately in Appendices E-1, E-2 and E-3 respectively.

The studied regulations for air and water control are dissimilar for the existing industry and new industry capacity; accordingly, it is convenient to separate the information for the existing industry from that for new capacity. The noise regulations, in contrast, are the same for both existing and new industry capacity, but different methods of analysis were used to estimate the corresponding costs of control; therefore, we maintained the existing/new industry approach in presenting the supporting data for this proposed regulation.

Note that all cost estimates are reported in mid-1975 dollars without further escalation during the studied period.

As mentioned in Chapter III of this report, the economic impact of compliance is measured in terms of the associated cost for an individual product or product sector. However, the studied regulations apply to the manufacturing processes, not the products. Thus, converting the cost of compliance from a specified process basis to an individual product basis is a necessary first step. A further complication is that a given product can often be made by more than one process or combination of processes, and the cost of compliance for these alternative methods may differ significantly. The process-to-product conversion therefore requires considerable judgment as to which manufacturing process is most likely to be used.

Table E-1 lists the process categories to which the EPA water effluent control regulations apply and the related product sectors used in the economic impact analysis. The tabulated numbers are percentages of the total process tonnages represented by the applicable product sectors. For example, the regulations (and their associated costs) for the unbleached kraft *process category* would apply to both the unbleached kraft paperboard and the unbleached kraft paper *product sectors*. Accordingly, the cost of compliance derived for the existing industry related to the unbleached kraft process category must be divided between the paperboard and paper sectors, in this case by a ratio of 86 to 14.

The table also shows that most products can be made by more than one process. The total costs of compliance for a given product therefore consist of the applicable portions of the costs for each related process.

Pages 65, 66 and 67 are Blank.

TABLE 5-1

PRODUCT SECTORS INCLUDED IN STUDIED PROCESS CATEGORIES
(Percentage of process category tonnage)

Process Category \ Product Sector	Unbl. Kraft Paper-board	Unbl. Kraft Paper	NSSC Corru. Medium	Recycled Paper-board	Coat. Paper	Bl. Board & Specials	Printing & Writing	Tissue	Newsprint	Bl. Pkg. & Ind. Conv. Paper	Soc. Ck Paper	Bl. Kraft Mkt. Pulp	Dissolving Pulp	TOTAL
Unbl. Kraft	96.3	34.9	–	–	–	–	–	–	–	–	–	–	–	100.0
NSSC	–	–	100.0	–	–	–	–	–	–	–	–	–	–	100.0
Unbl.Kraft/NSSC	58.5	21.9	19.7	–	–	–	–	–	–	–	–	–	–	100.0
Recycled Paperboard	–	–	–	100.0	–	–	–	–	–	–	–	–	–	100.0
Coat. Paper	–	–	–	–	100.0	–	–	–	–	–	–	–	–	100.0
Bleached Kraft	11.9	7.3	–	–	–	18.3	17.9	4.4	7.6	3.7	1.4	25.0	3.4	100.0
Sulfite	–	–	–	–	–	–	43.2	31.5	25.8	4.5	–	–	–	100.0
Dissolving Sulfite	–	–	–	–	–	–	–	–	–	–	–	–	100.0	100.0
Soda	–	–	–	–	–	–	100.0	–	–	–	–	–	–	100.0
Semi-Chem	–	–	–	–	–	–	64.6	18.9	16.5	–	–	–	–	100.0
Groundwood	–	–	–	–	–	–	40.6	–	59.7	–	31.1	–	–	100.0
NYT Thermo	–	–	–	–	–	–	–	100.0	–	–	–	–	–	100.0
NYT Pine	–	–	–	–	–	–	100.0	–	–	–	–	–	–	100.0

Source: Arthur D. Little, Inc., estimates, derived from information initially obtained from the American Paper Institute and National Council of Air & Stream Improvement.

Note that the bleached kraft process is used to make unbleached kraft products. This apparent anomaly is not an error; several mills produce both bleached and unbleached products. In the cost calculations, all mills that make a combination of products are included in those process categories with the higher costs for compliance.

In a similar manner, costs of compliance for the studied air regulations are also first developed on a process category and transformed to individual product sectors. However, the transformation is much simpler than for water control, since all processes except kraft have the same costs. In general, mills using the kraft process have air control costs that are an order of magnitude greater.

The cost to a given mill for compliance with OSHA noise regulations is associated with the type and number of manufacturing steps that it uses. Thus, it is immaterial whether a kraft or sulfite manufacturing process is used for pulp production, but it is important to identify whether the mill is integrated or nonintegrated, because this is related to the type and number of process steps that must be controlled. Hence, although OSHA noise regulations are not prescribed by process category, the process/product transformation analysis is a convenient method of estimating and allocating the cost of compliance.

The percentage of process category used in the manufacture of the individual product sectors may vary from year to year because new capacity for one process may replace or add to the capacity of a different process used in a studied product sector. The percentages shown here are for the in-place facilities during the early 1970 period.

APPENDIX E-1

AIR EMISSIONS CONTROL

A. CONTROL REGULATIONS

1. Existing Industry

Under the Clean Air Act, as amended in 1970, air quality standards have been established for the whole country. Each state is required to adopt and submit implementation plans to the Administrator of the Environmental Protection Agency for its emission reduction strategy and enforcement thereof to achieve national standards for particulates, sulfur oxides, nitrogen oxides, hydrocarbons, and carbon monoxide.

These State Air Quality Implementation Plans (SIPs) apply both to recovery boilers (used in the kraft and sulfite pulp manufacturing processes) and to power boilers used for steam and power generation. Further, SIP regulations vary widely from state to state, as shown in Table E-2. Since deriving costs of compliance on a state-by-state basis would be prohibitively expensive, ADL selected current SIP standards for a single state — Oregon — as the basis for deriving costs of compliance. Oregon was chosen because:

- its requirements are stated more explicitly;
- its requirements are more stringent than those of other key producing states; and
- its requirements (hence the associated costs) may become applicable to other states in the near future.

2. New Mills

The Environmental Protection Agency is planning to establish air pollution control standards for new kraft pulp mills. These standards, given in Table E-3, are at the proposal stage and are likely to be approved (possibly with some modifications).

The EPA also established air pollution control standards for new steam-generating boilers (Table E-4). These limit the emissions of particulates, sulfur dioxide, and nitrogen oxides. The standards for steam generating boilers are applicable to power boilers in the kraft pulp industry, as well as to other power boilers with capacities of more than 250 million Btu/hr.

B. COST MODELS, KRAFT MILLS

Particulate emissions from the kraft process occur primarily from the recovery furnace, the lime kiln, and the smelt dissolving tank. These emissions, which are caused mainly by the carry-over of solids plus sublimation and condensation of the inorganic chemicals, consist principally of sodium salts, but include some calcium salts from the lime kiln.

The characteristic odor of the kraft mill is caused largely by the emission of hydrogen sulfide. The major source is the direct contact evaporator, in which sodium sulfide in the black liquor reacts with carbon dioxide in the furnace exhaust. The lime kiln is another potential source, since a similar reaction occurs involving residual sodium sulfide in the lime mud. Lesser amounts of hydrogen sulfide are emitted with the noncondensible off gases from the digesters and multiple effect evaporators.

TABLE 5-1

[illegible] STANDARDS FOR AIR EMISSIONS FROM KRAFT MILLS IN SELECTED STATES
(Those left blank are not specified in the regulations)

	Kraft Pulp Mills					Sulfite Pulp Mills		
	Particulates Matter		Sulfur Dioxide	Total Reduced Sulfur		Particulates	Sulfur Dioxide	
	lb/ton ADP	lbs/hr	ppm	lb/ton ADP	ppm	lb/ton ADP	lb/ton ADP	ppm
GEORGIA								
Total	←						35	
Recovery Boiler	4		300	0.40[a]	5[b]	4		500
Smelt Tank	0.5	←						
Lime Kiln[c]	1	←		0.2[d]	40[e]	←		
Blow Systems	←						0.30	
ALABAMA								
Total	←							
Recovery Boiler	4	←		1.0[f]		←		
Smelt Tank	0.5	←				←		
Lime Kiln	1	←				←		
Blow Systems	←					←		
FLORIDA								
Total		40	←					
Recovery Boiler	2[g]	←			27.5[h]	←		
Smelt Tank	←							
Lime Kiln	←							
Blow Systems	←							
OREGON								
Total	←							
Recovery Boiler	←							
Smelt Tank	←							
Lime Kiln	←							
Blow Systems	←							
WASHINGTON								
Total	←							
Recovery Boiler	4	←				←		
Smelt Tank	0.5	←				←	40	
Lime Kiln	1	←				←		
Blow Systems	←							
WISCONSIN								
Total	←							
Recovery Boiler	←			0.4[i]	27.5[h]	←		
Smelt Tank	←							
Lime Kiln	←							
Blow Systems	←							

NOTES: [a] Noncondensibles from digester, multiple-effect evaporator, and steam or air stripping are burned in lime kiln.

[b] ASIL drop on July 1, 1979 to 0.1 lb/hour and 20 ppm

[c] ASIL drop on July 1, 1979 to 0.1 lb/hour and 20 ppm

[d] Calculation of unbleached pulp changed to digester

[e] expressed as H_2S (total TRS only)

[f] Bleach 1,200 lb black liquid solids fed to furnace

[g] Calculation of unbleached pulp changed to digester

SOURCE: "Preliminary Background Information for Standards of Performance for Pulp and Paper Industry," EPA, August 1973

TABLE 3-1

PROPOSED FEDERAL AIR EMISSION AND MONITORING REQUIREMENTS FOR NEW KRAFT MILLS

	Total Reduced Sulfur			Particulate Matter					Monitoring Requirements	Comments
	ppm[a]	lb/T ADP	g/kg ADP	g/Nm³	g/dscm	lb/T ADP	g/kg ADP	Opacity		
Recovery Furnace System	5[b]	0.15	0.075	0.044	0.1[b]	1.0	1.0	35	Opacity, TRS & O_2	Particulate & TRS corrected to 8% O_2
Lime Kiln	5[b]	0.025	0.0125	0.067 gas	0.15[b] gas	0.15	0.075	None	TRS & O_2	Particulate & TRS corrected to 10% O_2
				0.13 oil	0.30[b] oil	1.87	0.936	None	TRS & O_2	Particulate & TRS corrected to 10% O_2
Smelt Tank	5	0.025	0.0125[b]	0.052	0.119	0.3	0.15[b]	None		Break water will insure compliance
Brown Stock Washer System	5[b]	0.01	0.005	———	No Standard	———			TRS[c] or Temperature	Likely to be utilized as combustion air in the recovery furnace
Black Liquor Oxidation System	5[b]	0.01	0.005	———	No Standard	———			TRS[c] or Temperature	Likely to be utilized as combustion air in the recovery furnace
Condensate Stripping System	5[b]	0.01	0.005	———	No Standard	———			TRS[c] or Temperature	Likely to be combined to the lime kiln
Digester System	5[b]	0.01	0.005	———	No Standard	———			TRS[c] or Temperature	Likely to be combined to the lime kiln
Multiple-Effect Evaporator System	5[b]	0.01	0.005	———	No Standard	———			TRS[c] or Temperature	Likely to be combined to the lime kiln

[a] By volume, dry basis, 4 hr average

[b] Technical guidelines and notes used to specify limits in recommended standard

[c] In most instances, monitoring will not be required, since these sources will be utilized in the lime kiln or recovery furnace. If they are combined in separate incinerators or power boilers, only the temperature and oxygen content will be monitored.

Source: Arthur D. Little, Inc., estimates

TABLE F-4

STANDARDS OF PERFORMANCE FOR NEW STEAM GENERATORS
HAVING CAPACITY GREATER THAN 250 MM BTU/HR

Particulate = 0.18 g/MM cal (0.1 lb/MM Btu)

= Opacity[a] less than 20%

SO_2 = 1.4 g/MM cal (0.8 lb/MM Btu) for liquid fuel

= 2.2 g/MM cal (1.2 lb/MM Btu) for solid fuel

NO_x = 0.36 g/MM cal (0.2 lb/MM Btu) for gaseous fuel

= 0.54 g/MM cal (0.3 lb/MM Btu) for liquid fuel } Measured as NO_2

= 1.26 g/MM cal (0.7 lb/MM Btu) for solid fuels except lignite

[a] Failure to meet this requirement because of the presence of uncombined water is not a violation of the opacity standard.

Source: EPA, "Standard Support & Control Info Help and Paper," Draft, December, 1971

The kraft process odor also results from an assortment of organic sulfur compounds, all of which have extremely low odor thresholds. Methyl mercaptan and dimethyl sulfide are formed in reactions with the wood component lignin. Dimethyl disulfide is formed through the oxidation of mercaptan groups derived from the lignin. These compounds are emitted from many points within a mill; the main sources, however, are the digester/blow tank systems and the direct contact evaporator.

The cost to achieve various levels of control is presented for each of the affected facilities for three sizes of kraft mills: 500, 1000, and 1500 tons of air dried pulp per day. The credit represents the value of recovered salt cake.

The cost of air pollution per ton of pulp is calculated on the basis of 325 operating days per year.

1. Recovery Boiler

There are two types of recovery boilers: (1) conventional recovery boilers and (2) non-contact boilers. The conventional recovery furnace system employs a direct contact evaporator, using the hot flue gas from the furnace to evaporate water from the black liquor feed to the furnace. The direct contact evaporator removes some of the particulates from the flue gas. In addition, the physical properties of the particulate are somewhat different from those of the noncontact furnace case. Because of these factors, the electrostatic precipitator (ESP) on the noncontact furnace must be larger (and more expensive) to achieve the same exit particulate concentration.

Capital costs, annual costs, and credits for recovered particulate are shown in Table E-5 for three different cases: (1) economic recovery, (2) particulate emission control to meet state standards, and (3) particulate emission control to meet federal standards.

Since the particulate is a valuable material (mainly salt cake), it is economical to recover the particulate emissions up to a certain level; beyond this, the value of the additional particulate recovered is not enough to justify the additional investment. (That is, the incremental return on the incremental investment drops below the acceptable level for that company.) AEH, has used an economic recovery level of 97.5% control efficiency, which is based on a survey of existing control devices on recovery furnaces.[1]

The capital cost of the ESP is based upon the recent quotations and cost information given in the IGCI report.[2]

The credit for recovered particulate is calculated on the assumption that all the particulate is salt cake valued at $35/ton. The air pollution control cost is actually the incremental cost of the particulate device over that of the device used for economic recovery. The incremental capital cost, the incremental operating cost, and the incremental operating cost per ton of pulp are given in Table E-5.

1. "Particulate Matter Reduction Trends in the Kraft Industry," Technical Bulletin No. 39, National Council of the Pulp and Paper Industry for Air and Stream Improvement, Inc., April 4, 1967.

2. "Air Pollution Control Technology and Costs in Eight Selected Industries," Industrial Gas Cleaning Institute, EPA Contract No. 68-02-1081, Draft Report, 1974.

TABLE E-5

CONTROL COSTS FOR RECOVERY BOILERS[A]
(Credits based on a value of $35/ton for recovered chemicals)

	MILL SIZE (tpd)		
	500	1,000	1,500
ECONOMIC RECOVERY (97.5%)			
Conventional Boiler + ESP			
Capital Cost, $	1,846,000	2,783,000	3,550,000
Gross Annual Operating Cost, $	459,000	696,000	888,000
Credits, $/yr	(612,000)	(1,225,000)	(1,835,000)
Noncontact Boiler + ESP			
Capital Cost, $	2,720,000	4,122,000	5,258,000
Gross Annual Operating Cost, $	571,000	866,000	1,104,000
Credits, $/yr	(1,198,000)	(2,397,000)	(3,595,000)
STATE STANDARDS (99%)			
Existing Conventional Boiler + ESP			
Capital Cost, $	2,040,000	3,092,000	3,944,000
Gross Annual Operating Cost, $	510,000	773,000	986,000
Credits, $/Yr	(623,000)	(1,246,000)	(1,868,000)
Existing Noncontact Boiler + ESP			
Capital Cost, $	3,022,000	4,580,000	5,842,000
Gross Annual Operating Cost, $	635,000	962,000	1,227,000
Credits, $/Yr	(1,216,000)	(2,434,000)	(3,649,000)
FEDERAL STANDARDS (99.7%)			
New Conventional Boiler + ESP			
Capital Cost, $	2,448,000	3,710,000	4,733,000
Gross Annual Operating Cost, $	563,000	853,000	1,089,000
Credits, $/Yr	(621,000)	(1,243,000)	(1,864,000)
New Noncontact Boiler + ESP			
Capital Cost, $	3,400,000	5,151,000	6,573,000
Gross Annual Operating Cost, $	716,000	1,082,000	1,380,000
Credits, $/Yr	(1,225,000)	(2,451,000)	(3,676,000)

Source: Arthur D. Little, Inc., estimates

[A] Total installed cost based upon recent price quotation for ESP and on 1974 EPA air regulations for economic recovery level.

The methods used to reduce TRS emissions from the conventional recovery furnaces are close monitoring and control of the process variables and oxidation of the black liquor to eliminate the compounds that cause TRS emissions when the black liquor contacts the furnace flue gas in the direct contact evaporator. No costs are assessed for the required closer control of the process variables.

The control technique for reducing TRS emissions is inherent in the basic design of the noncontact furnace system. A direct contact evaporator is not used; its function is achieved by any of several methods, such as increasing the economizer section to recover more heat from the flue gas, adding a steam-heated concentrator to evaporate water from the black liquor, or using combustion air heated by the furnace flue gas to evaporate water from the black liquor in an air contact evaporator. In general, less heat is recovered from the noncontact furnace flue gases than from conventional furnace flue gases; as a result noncontact furnace flue gases are about 120°F hotter than those from conventional furnaces. The odor control cost is the combined cost of the incremental loss of heat energy in the flue gas and the incremental operating cost of the noncontact furnace over the operating cost of the conventional furnace. These costs are not included in Table E-5.

2. Lime Kiln

The most common type of particulate control device for the lime kiln is the venturi scrubber. As in the recovery boiler, a certain amount of recovery is economically favorable. For the lime kiln, the economic recovery level is assumed to be achieved with a venturi scrubber at 37.5 cm (15 inches) of water pressure drop.[3] Two other venturi scrubbers with higher pressure drops are also considered as alternatives. Capital cost estimates were based on recent quotations and on a study done for EPA by the Industrial Gas Cleaning Institute.[4]

The cost attributed to air pollution control is the cost difference between the scrubber with the 37.5-cm pressure drop and the higher powered scrubbers. (Table E-6).

Proper process conditions such as the cold-end temperature, the oxygen content in the kiln, the sulfide content in the lime mud, and the pH and sulfide content of the scrubbing water are necessary to reduce TRS emissions from the lime kiln. Cold-end temperature control is a well-defined process for controlling TRS emissions. The costs given in Table E-6 are based on increasing the cold-end temperature from 350°F to 450°F.

Scrubbing with a caustic solution will absorb some of the TRS emission from the lime kiln. For most mills the caustic is part of the ordinary makeup caustic to the mill, and no cost is associated with this alternative.

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3 EPA, Air Regulations, 1975

4 "Air Pollution Control Technology and Costs in Seven Selected Areas." Industrial Gas Cleaning Institute. EPA Contract No. 68-02-0299, December 1973

TABLE 8-6

CONTROL COSTS FOR LIME KILN SYSTEM

	MILL SIZE (tpd)		
	500	1,000	1,500
Economic Level			
Venturi Scrubber (37.5 cm WG)			
Capital Cost, $	87,000	123,000	156,000
Gross Annual Operating Cost, $	41,600	77,000	111,000
Credits, $/Yr	(63,600)	(127,200)	(190,800)
Existing Mill			
Venturi Scrubber (50 cm)			
Capital Cost, $	155,000	235,000	300,000
Gross Annual Operating Cost, $	52,600	98,200	141,000
Credits, $/Yr	(65,800)	(131,600)	(197,400)
New Mill			
Venturi Scrubber (75 cm)			
Capital Cost, $	196,000	297,000	379,000
Gross Annual Operating Cost, $	66,500	124,000	178,600
Credits, $/Yr	(66,200)	(132,400)	(198,600)
Process Control Cost[a]			
Annual Operating Cost, $	17,500	38,300	60,300
Cost per ton, $	0.108	0.118	0.124

[a] Based on the fuel cost to increase the cold-end temperature 100°F

Source: Arthur D. Little, Inc., estimates

3. Smelt Dissolving Tank

Three control techniques are presented in Table E-7 for the smelt dissolving tank. Demisters are used to achieve an economic recovery level. Their cost, based on the Sirrine report,[5] includes the mesh pad and a water spray system. A credit of $35/ton is assigned to the recovered particulate. The weight of the recovered material is based on the emission factor given in the MRI report,[6] using a collection efficiency of 80% for the mesh pad.

A packed tower with associated fan, liquid circulation pump, and control is used as an alternative control device for the smelt dissolving tank. Credits for recovered particulate are calculated in the same manner as for the demister, except that the recovery efficiency is 90%.

The other alternative device considered in Table E-7 is an orifice scrubber with associated fan, liquid circulation pump, and control. Its cost is based on recent quotations. The collection efficiency of the orifice scrubber (20-25 cm WG) is at least 97%.

The control technique for reducing TRS emissions from the smelt dissolving tank is to use fresh water in the scrubber. No control costs are presented for control of TRS emissions, since this feature can be designed into a new mill at essentially no cost.

4. Digesters and Multiple-Effect Evaporators

The vent gas streams from the digesters and the multiple-effect evaporators are similar and contain TRS compounds. These gases present an odor problem. Since it is common practice to treat the combined emissions from both facilities, the control costs are estimated accordingly. The costs presented in Table E-8 assume incineration in the lime kiln. The system consists of the necessary piping and blowers to collect the gas streams and delivery piping and controls to inject the gases into the lime kiln. The spare incinerator would handle the gases when the lime kiln is not operating.

The digester affects the cost of the control system. The control costs for both cases (batch or continuous digester, and multiple-effect evaporator), based on the Sirrine report, are shown in Table E-8.

5. Brown Stock Washers

The gas from the brown stock washers is a relatively large stream with a low concentration of TRS. The only control technique is incineration in the recovery furnace. Cost estimates by the EPA are given in Table E-9. The control equipment consists of the necessary piping and controls to inject the gases into the recovery furnace and hoods, connecting piping, and controls to collect the gases.

6. Black Liquor Oxidation System

One method of reducing TRS emissions from conventional recovery furnaces is to oxidize the black liquor; this eliminates the compounds that cause TRS emissions when the black liquor contacts the furnace flue gas in the direct contact evaporator.

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5. Control of Atmospheric Emissions in the Wood Pulping Industry. Environmental Engineering Inc. and J.E. Sirrine Company. EPA Contract No. CPA-22-69-18. March 1970.

6. MRI Report. EPA Contract CPA-22-69-104. Handbook of Emissions, Effluents, and Control Practices for Stationary Particulate Pollution Sources. November 1970.

TABLE E-7

CONTROL COSTS FOR SMELT TANK SYSTEM

	MILL SIZE (tpd)		
	500	1,000	1,500
Economic Level Mesh Pad (80%)			
Capital Cost, $	21,000	25,000	31,000
Gross Annual Operating Cost, $	4,100	4,700	5,700
Credits,[a] $/yr	(11,400)	(22,700)	(34,100)
Existing Mill Packed Tower (max. 96%)			
Capital Cost, $	77,000	121,000	153,000
Gross Annual Operating Cost, $	19,700	34,000	46,000
Credits,[a] $/yr	(13,600)	(27,300)	(40,900)
New Mill Orifice Scrubber (97%)			
Capital Cost, $	117,000	160,000	195,000
Gross Annual Operating Cost, $	50,000	74,600	101,200
Credits[a], $/yr	(13,800)	(27,600)	(41,400)

[a] Based on recovered particulate at $35/ton

Source: Arthur D. Little, Inc., estimates

TABLE E-8

CONTROL COSTS FOR DIGESTER AND MULTIPLE-EFFECT EVAPORATORS
(Based on incineration in the lime kiln; costs include evaporator and separate incinerator)

	MILL SIZE (tpd)		
	500	1000	1500
Batch Digester			
Capital Cost, $	162,000	235,000	318,000
Annual Operating Cost, $	35,000	54,000	73,500
Cost per Ton, $	0.216	0.165	0.151
Continuous Digesters			
Capital Cost, $	102,000	156,000	205,000
Annual Operating Cost, $	25,000	39,500	54,000
Cost per ton, $	0.155	0.121	0.110

Source: Arthur D. Little, Inc., estimates

TABLE E-9

CONTROL COSTS FOR THE BROWN STOCK WASHERS
(Based on incineration in the Recovery Furnace)

	MILL SIZE (tpd)		
	500	1000	1500
Capital Cost, $	164,000	252,000	318,000
Annual Operating Cost, $	29,500	46,000	58,000
Cost per ton, $	0.182	0.142	0.119

Source: Arthur D. Little, Inc., estimates

The black liquor may be oxidized to reduce TRS emissions from the recovery boiler. The effluent gases from oxidation with air represent an emission source. (No emissions are generated when black liquor is oxidized with oxygen.) If the recovery boiler is a new source, federal regulations would require treatment of the gases. The control method is to incinerate the gases in the recovery furnace. Since the off gas stream has a high moisture content, a condenser is necessary. The control costs are shown in Table E-10.

7. Condensate Stripper

In mills that have condensate strippers, the TRS compounds vented from them can be controlled by incineration. The cost estimates shown in Table E-11 are based on a system that includes a fan, duct, seal pot, and flame arrester. The duct begins at the overhead condenser on the stripper and ends at the point where it connects with the noncondensible gas heater that leads to the lime kiln and the spare incinerator.

C. COST MODELS, POWER BOILERS

Bark boilers, or combination boilers (bark and oil, or bark and coal) are used as power boilers in the pulp industry. The emissions from a bark boiler are primarily particulates (bark char, fly ash, and sand). Unlike most other stacks on a kraft mill, no significant gaseous air pollutants are emitted, and unlike most coal fired boilers, there is no SO_2 problem, since there is little or no sulfur in the bark.

The SO_2 problem in the combination boilers will depend on the fraction of the coal or oil used in the boiler and the sulfur content of the fuel. No SO_2 control systems are installed in the pulp industry, so the cost of such systems is not discussed here.

Bark fly ash, unlike most fly ash, is primarily unburned carbon. Collected and reinjected, it can increase boiler efficiencies from 1% to 4%.

The air pollution control system for boilers consists of a mechanical collector followed by an electrostatic precipitator or scrubber. The cost of a mechanical collector is not included, since the char collected from the mechanical collector is recycled and the recovery is considered economic, rather than attributed to pollution control.

The cost of electrostatic precipitators for bark boilers and combination boilers of different capacities is given in Table E-12. The cost for the bark boilers was obtained from the IGCI report,[1] and the cost for the combination boilers was obtained from recent quotations. The boiler having a rated steam capacity of 350,000 lb/hr was for a 600 tpd (bleached) air dried pulp mill.

D. EXISTING INDUSTRY AGGREGATE COST

The total incremental cost to the existing industry to rise from the 87.5% economic recovery level to the SIP standard of 99.0% recovery was estimated in three broad areas: (1) controls for kraft pulp mills, (2) controls for power boilers, and (3) the early retirement of existing kraft recovery boilers.

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1. Air Pollution Control Technology and Costs in Nine Selected Areas. EPA report 68-02-0301 by Industrial Gas Cleaning Institute, September 1972.

TABLE E-10

CONTROL COSTS FOR BLACK LIQUOR OXIDATION

	MILL SIZE (tpd)		
	500	1,000	1,500
Air Oxidation			
Capital Cost, $	333,000	484,000	649,000
Annual Operating Cost, $	113,000	168,000	231,000
Cost per ton, $	0.695	0.517	0.474
Control of Offgasses (New Sources)			
Capital Cost, $	175,000	267,000	347,000
Annual Operating Cost, $	47,000	78,000	107,000
Cost per Ton, $	0.290	0.239	0.220

Source: Arthur D. Little, Inc., estimates

TABLE E-11

CONTROL COSTS FOR CONDENSATE STRIPPER
(Based on Incineration in lime kiln)

	MILL SIZE (tpd)		
	500	1,000	1,500
Capital Cost, $	13,000	18,600	23,000
Annual Operating Cost, $	4,700	5,800	6,700
Cost per Ton, $	0.029	0.018	0.014

Source: Arthur D. Little, Inc., estimates

TABLE E-12

CONTROL COSTS FOR POWER BOILERS

	Rated Steam Load, lb/hr	
	100,000	300,000
COAL BOILER		
ESP (99%)		
Capital Cost, $	566,000	736,000
Annual Operating Cost, $	91,000	184,000
ESP (99.7%)		
Capital Cost, $	440,000	886,000
Annual Operating Cost, $	110,000	221,000
COAL/OIL BOILER (1/3 Coal, 2/3 Oil)	250,000	350,000
ESP (99%)		
Capital Cost, $	880,000	1,080,000
Annual Operating Cost, $	220,000	270,000
ESP (99.7%)		
Capital Cost, $	1,062,000	1,300,000
Annual Operating Cost, $	266,000	325,000

Source: Arthur D. Little, Inc., estimates

1. Controls for Kraft Pulp Mills, Summary

Air control units costs for existing kraft mill models were estimated previously by process step and are summarized in Table E-13. Note that a conventional recovery boiler is assumed.

2. Power Boiler Controls for Other Categories

The average unit cost for power boiler controls in other process categories was not estimated on an engineering basis, because such an estimate would require a mill-by-mill survey to determine applicable standards and approximate costs. The cost calculated for the kraft categories was assumed to apply.

3. Retirement of Recovery Boilers in Kraft Categories

It is standard industry practice to operate kraft recovery boilers considerably above their nominal capacity, but stringent SIP standards for removal of particulates and TRS usually cannot be met under these conditions. Thus, the imposition of SIP standards generally requires the addition of incremental recovery boiler capacity, or the replacement of existing capacity with a larger unit, so that boilers may be operated near their nominal capacity without loss of pulping capacity in the mill.

AEH did not attempt mill-by-mill engineering estimates for this item. Its total industry cost estimates include a capital allotment for premature recovery boiler replacement based on total capacity, to acknowledge that this is a legitimate and significant expense in complying with SIP regulations. The total cost for this item is estimated at 20% to 25% of the total replacement value of recovery boilers in the kraft categories.

4. Expenditures Through 1974

According to industry reports, about one third of all mills were in compliance in 1974. This was interpreted as meaning that one third of the total capital investment for compliance with SIP standards (including the economic recovery level) had been made by 1974. AEH distributed capital and operating costs by assuming that all mills had achieved the economic recovery level, and that additional expenditures would be proportional to capacity throughout the kraft categories. This rough approximation is probably adequate for estimating total industry costs and costs by major process and product sectors, and for the total industry to achieve compliance with SIP standards.

AEH further assumed that 80% of the incremental cost of compliance will be expended in the period 1975 to 1977 and 20% thereafter. It is apparent that uniform compliance with SIP standards will not be achieved by 1977; however, the 80/20 percentage distribution over the studied time period is only an approximation.

5. Summary Control Costs

Costs of compliance with SIP standards are aggregated by major kraft process category and mill size in Table E-14. They are allocated into major process subcategories used in this study (see Table III-7.) Note that the operating costs indicated are for operation and maintenance (O&M) only; as required for the impact analysis methodology, depreciation and cost of capital are excluded. The process to product transformation discussed previously was applied to establish the cost of compliance by product sector (Table III-8). Recall that the costs for SIP standards were developed incrementally from the assumed 97.5% "economic level of recovery"; these costs would be appreciably different had another economic recovery level been assumed.

| | | |

[illegible]

[illegible]

(Thousands of [illegible])

Process Category		1977 Capacity (Bbl/cd)	Economic Level for Process Controls		Economic Level to ITP Level for Process Controls		Recovery Sulfur Requirement[a]	Total Economic Level to ITP Standards	
			Capital	Annual Operating (O&M)	Capital	Annual Operating (O&M)	Capital	Capital	Annual Operating (O&M)
Bleached Kraft:	Small	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Medium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Large	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sub-Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Unbleached Kraft:	Small	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Medium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Large	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sub-Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Kraft/NSSC	Small	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Medium	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Large	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Sub-Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Other Categories		[illegible]	--	--	[illegible]	[illegible]	--	[illegible]	[illegible]
	TOTAL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible][b]	[illegible][b]	[illegible]
Declared Expenditures through 1975									
Bleached Kraft			[illegible]	[illegible]	[illegible]	[illegible]	--	[illegible]	[illegible]
Unbleached Kraft			[illegible]	[illegible]	[illegible]	[illegible]	--	[illegible]	[illegible]
Kraft/NSSC			[illegible]	[illegible]	[illegible]	[illegible]	--	[illegible]	[illegible]
Other			--	--	--	--	--	--	--
TOTAL EXPENDITURES			[illegible]	[illegible]	[illegible]	[illegible]	--	[illegible]	[illegible]
NET TOTAL			--	--	[illegible]	[illegible][b]	[illegible]	[illegible][b]	[illegible][b]

[a] Recovery Sulfur approximated to ITP and Subcat. levels was used as the basis for eliminating combustion (kraft and all) power boiler costs.

[b] Rounded off

Source: Arthur D. Little, Inc., estimates

E. NEW MILLS, UNIT COSTS FOR SELECTED EXAMPLES

To estimate new mill manufacturing costs, ADL adapted the air control cost estimates prepared for kraft process sources and combination boilers. Table E-15 is a summary of the control costs for new kraft mill sources (excluding power boiler) for 500 and 1000 tons per day. The costs for the studied 800-tpd bleached kraft pulp mill and a 1000-tpd unbleached kraft pulp mill were extrapolated from these base cost estimates by use of the 0.6 factor. New mill sources were based on a conventional recovery boiler with black liquor oxidation for TRS control.

Note that incremental costs (capital and operating) are shown for the upgrading from "economic level" to SIP standards and from SIP standards to federal regulations. This differs from the presentation of the summary cost estimates for new mills (Table III-12), where the incremental cost reported is that from "economic level" to federal requirements.

While the total cost for treating air emissions is a relatively "hard" number (i.e., within the accuracy of pre-engineering cost estimates), the increment ascribed to the "economic level" and subsequently to the various standards is more arbitrary. The value of chemicals and makeup chemicals used at any given installation could vary widely; and thus has a profound effect upon the "economic level" of control. As noted, ADL used EPA's estimate of 97.5% particulate recovery as the "economic level"; obviously, if a smaller percentage were used, the incremental capital and operating costs of compliance would be substantially greater.

Table E-16 summarizes air control costs (including power boiler) for new mills producing the specific product grades selected for economic modeling. Air control costs have been treated the same as all other pulp mill costs; that is, a portion of total pulp mill cost is allocated to a paper or board product in direct proportion to the percentage of pulp mill output used by that product. (See Section 1g of Appendix F.)

TABLE 8-15

[illegible] OF AS CAPITAL COST ESTIMATES FOR BFW PULP MILL
(Thousands of dollars)

Item	Economic Level (BAT TP)		Increment from Eco. Level to STP Standards (BPT)		Increment from STP to Federal Standards (NS TP)	
	Capital	Annual Operating (O&M)	Capital	Annual Operating (O&M)	Capital	Annual Operating (O&M)
A. 1000 tpd Bleached Kraft						
Recovery Boiler	2,760	(Rec)	555	–	420	–
Lime Kiln	220	(Rec)	170	–	60	15
Smelt Tank	30	(Rec)	40	10	40	35
Digester & Evaporators	–	–	160	24	–	–
Black Liquor Oxidation	–	–	270	30	–	–
Brown Stock Washers and Condensate Stripping	–	–	270	–	–	–
TOTAL	2,950	(1030)	1,250	64	720	50
B. 500 tpd Bleached Kraft						
Recovery Boiler	1,840	(429)	700	–	420	–
Lime Kiln	90	(35)	70	–	40	9
Smelt Tank	30	(10)	40	5	40	25
Digester & Evaporators	–	–	160	10	–	–
Black Liquor Oxidation	–	–	240	22	–	–
Brown Stock Washers and Condensate Stripping	–	–	230	–	–	–
TOTAL	1,960	(475)	780	36	480	31

Source: Arthur D. Little, Inc., estimates

TABLE V-16

AIR CONTROL COSTS, NEW MILL SOURCES, BY PRODUCT SECTOR
(thousands of dollars)

Product and Capacity	Economic Level (97.5%) Capital	Economic Level (97.5%) Annual Operating (O&M)	Increment to SIP Standards (99%) Capital	Increment to SIP Standards (99%) Annual Operating (O&M)	Increment to Federal Standards (99.7%) Capital	Increment to Federal Standards (99.7%) Annual Operating (O&M)
Unbleached Kraft Liner 1000 tpd						
Pulp Mill	2,800	(930)	1,100	60	650	50
Power Boiler	0	0	900	90	200	20
TOTAL	2,800	(930)	2,000	150	850	70
Integrated to 800 tpd Unbleached Kraft						
o Kraft Bag Paper, 230 tpd						
Pulp Mill	700	(210)	310	10	190	10
Power Boiler	0	0	250	25	50	5
TOTAL	700	(210)	560	35	240	15
Semi-Chemical Corrugating Medium, 450 tpd						
Pulp Mill	0	0	0	0	0	0
Power Boiler	0	0	900	93	200	20
TOTAL	0	0	900	93	200	20
Integrated to 500 tpd Bleached Kraft						
o Market Pulp, 800 tpd						
Pulp Mill	2,600	(830)	1,060	55	660	45
Power Boiler	0	0	1,160	116	260	24
TOTAL	2,600	(830)	2,220	171	880	69
o SBS Board, 500 tpd						
Pulp Mill	1,600	(690)	690	50	410	30
Power Boiler	0	0	830	83	170	17
TOTAL	1,600	(690)	1,520	121	580	47
o Bond Paper, 300 tpd						
Pulp Mill	1,000	(300)	370	20	230	10
Power Boiler	0	0	500	50	100	10
TOTAL	1,000	(300)	870	70	330	20
o Book Paper, 300 tpd						
Pulp Mill	1,000	(300)	370	20	230	10
Power Boiler	0	0	580	58	120	12
TOTAL	1,000	(300)	950	78	350	22
o Tissue, 163 tpd						
Pulp Mill	500	(160)	190	20	110	10
Power Boiler	0	0	250	25	50	5
TOTAL	500	(160)	440	45	160	15
o Newsprint, 550 tpd						
Pulp Mill (150 tpd Kraft)	500	(150)	120	13	80	7
Power Boiler	0	0	500	50	100	10
TOTAL	500	(150)	620	63	180	17
Sulfite Dissolving Pulp 550 tpd						
Pulp Mill	0	0	0	0	0	0
Power Boiler	0	0	900	90	200	20
TOTAL	0	0	900	90	200	20
All Other Products	No federal air control costs					

TABLE E-16 (cont'd)

AIR CONTROL COSTS, NEW MILL SOURCES, BY PRODUCT SECTOR
(thousands of dollars)

	Increment to SIP Standards[1]	
	Capital	Annual Operating (O&M)
RECYCLED PAPERBOARD		
Recycled Boxboard, 400 tpd	300	70
Jute Linerboard, 330 tpd	300	60
Bogus Medium, 330 tpd	200	50
Gypsum Linerboard, 400 tpd	300	60
RECYCLED NEWSPRINT, 330 tpd	200	60
DEINKED TISSUE, 75 tpd	100	10

(1) Standards and costs apply to SIP requirements for power boilers. There is no economic particulate recovery level. There are no applicable federal standards for these mills.

APPENDIX E-2

WATER EFFLUENT CONTROL

A. CONTROL REGULATIONS

The Federal Water Pollution Control Act Amendment of 1972 states: "It is the national goal that the discharge of pollutants into navigable waters be eliminated by 1985." Working toward this goal incrementally, EPA has promulgated and proposed two interim levels of water effluent control — one for the existing industry and the other for new sources. An additional, more stringent level of control will have to be imposed beyond these interim objectives to achieve the 1985 goal.

1. Existing Industry

Water effluent guidelines based on the Best Practical Control Technology Currently Available (BPT) were promulgated for 1977. Table E-17 summarizes the specified limits of BOD and suspended solids by process categories. Note that the specifications indicate a maximum discharge for a single day and for a 30-day average. Wherever the maximum daily discharge is specified, it is about 1.7 times greater than the 30-day average level; this reflects the fact that occasional large discharges can be tolerated, because they tend to be balanced by low levels on other days when averaged over a month.

Note also that color removal is not specified for the BPT level of control. A more stringent control level — Best Available Technology Economically Achievable (BAT) — was proposed for 1983. These regulations (Table E-18) would reduce the permissible amount of BOD and suspended solids by about 50% and also require color removal in certain categories.

2. New Mills

New Source Performance Standards (NSPS) were proposed for all new plant construction. In most categories, these regulations are less stringent in BOD and suspended solids removal than the BAT regulations. Further, unlike the BAT regulations proposed for existing mills, color removal is not specified. Table E-19 presents the specific requirement for each of the studied process subcategories. Again, note that the daily permissible level of discharge is higher than the 30-day average.

B. DATA BASE — THE DEVELOPMENT DOCUMENTS[1]

ADL was not retained to develop engineering cost estimates for compliance with the studied regulations; it was expected to rely upon unit cost data published in the EPA Development

1. The "Development Documents" referred to in this appendix include the following:

   - "Development Document for Advanced Notice of Proposed or Promulgated Rule Making for Effluent Limitations Guidelines and New Source Performance Standards for the Bleached Kraft, Groundwood, Sulfite, Soda, Deink, and Non-integrated Paper Mills Segment of the Pulp, Paper and Paperboard Point Source Category." EPA 440/1-75/047, August 1975.
   - "Development Document for Interim Final and Proposed Effluent Guidelines and Proposed New Source Performance Standards for the Bleached Kraft, Groundwood, Sulfite, Soda, Deink and Non-integrated Paper Mills Segment of the Pulp, Paper, and Paperboard Point Source Category." Vol. 1, EPA 440/1-76/047-a, January 1976.
   - "Development Document for Effluent Limitations Guidelines and Standards of Performance: Fine Paper, and Paperboard Industry." draft report to EPA by Wapora, Inc., June 1973.
   - "Development Document for Effluent Limitations Guidelines and Standards of Performance: Builders Paper and Board Industry." draft report to EPA by Wapora, Inc., June 1973.

TABLE I-1/

EPA WATER EFFLUENT GUIDELINES, BPT (1977)
(lb/ton)

Process Subcategory	BOD_5 Limit		TSS Limit	
	Max. 30-Day Avg.	Max. Day	Max. 30-Day Avg.	Max. Day
Unbleached Kraft	6.0		6.0	
NSSC Medium				
Sodium Base	10.0		10.0	
Ammonia Base	10.0		10.0	
Unbleached Kraft/NSSC	7.0		7.0	
Recycled Paperboard	2.0		2.0	
Construction Paper	5.0		3.0	
Bleached Kraft				
BCT Kraft	12.7	21.5	20.6	45.2
Fine Kraft	9.4	15.8	14.7	32.1
Dissolving Kraft	25.9	43.9	31.1	68.1
Market Kraft	18.2	24.1	20.6	45.2
Sulfite	30.6	51.5	42.3	92.8
Dissolving Sulfite	43.6	77.0	52.5	115.1
Soda	11.5	19.5	16.6	36.4
Deinked	16.0	23.8	25.3	55.6
Groundwood				
C-R-K Paper	8.6	14.2	14.0	30.7
Chemi Mechanical	7.0	11.9	11.8	25.8
Therm-Mechanical	5.2	8.8	8.9	19.6
Fine Papers	7.5	12.7	12.9	28.2
B/I Tissue	9.5	15.8	9.3	20.5
B/I Fine	8.6	14.2	8.5	18.7

pH for all subcategories shall be between 6.0 to 9.0.

Source: EPA Development Documents

TABLE K-18

EPA WATER EFFLUENT GUIDELINES, BAT (1983)
(lb/ton)

Process Subcategory	BOD5 Limit		TSS Limit		Color	
	Max 30-Day Avg.	Max. Day	Max. 30-Day Avg.	Max. Day	Max. 30-Day Avg.	Max. Day
Unbleached Kraft	2.0		1.0		12.0	-
NSSC Medium						
Sodium Base	1.5		5.0		12.0	
Ammonia Base	1.5		5.0		7.0	
Unbleached Kraft/NSSC	1.5		1.5		8.0	
Recycled Paperboard	1.0		1.0		-	-
Construction Paper	2.5		1.5		-	-
Bleached Kraft						
BCT Kraft	5.7	11.6	3.7	8.1	130	260
Fine Kraft	3.8	8.0	3.1	6.7	130	260
Dissolving Kraft	10.9	22.5	6.9	15.2	250	500
Market Kraft	6.7	13.8	5.5	9.9	190	380
Sulfite	12.9	26.6	6.3	13.8	-	-
Dissolving Sulfite	16.7	35.6	8.1	17.7	-	-
Soda	4.8	10.0	3.1	6.7	130	260
Deinked	5.0	10.6	4.8	10.6	-	-
Groundwood						
C-R-S Papers	3.5	7.3	2.6	5.8	-	-
Chemi-Mechanical	2.5	5.2	2.4	5.3	-	-
Thermo-Mechanical	2.2	4.5	1.3	2.8	-	-
Fine Papers	3.3	6.9	2.4	2.0	-	-
B/I Tissue	4.0	8.3	1.9	4.2	-	-
B/I Fine	2.5	5.2	1.3	2.8	-	-

pH for all subcategories shall be between 6.0 and 9.0.

Dashes indicate that color removal is not required.

Source: EPA Development Documents

TABLE I-17

EPA WATER EFFLUENT GUIDELINES, NSPS
(lb/ton)

Process Subcategory	BOD5 Limit		TSS Limit		Color	
	Max 30-Day Avg.	Max. Day	Max. 30-Day Avg.	Max. Day	Max. 30-Day Avg.	Max. Day
Unbleached Kraft	1.5		3.0		25	-
NSSC Medium						
Sodium Base	5.0		6.0		30	
Ammonia Base	5.6		6.0		30	
Unbleached Kraft/NSSC	6.5		6.0		27	
Recycled Paperboard	1.5		1.5		-	-
Construction Paper	4.0		2.5		-	-
Bleached Kraft						
BCT Kraft	5.7	11.8	7.2	15.9	-	-
Fine Kraft	3.8	8.0	6.1	13.5	-	-
Dissolving Kraft	10.9	22.5	14.0	30.7	-	-
Market Kraft	3.7	7.6	5.2	11.3	-	-
Sulfite	8.2	17.0	7.9	17.3	-	-
Dissolving Sulfite	16.7	35.6	16.1	35.3		
Soda	5.8	10.9	5.1	11.5	-	-
Deinked	7.5	15.6	7.2	15.9	-	-
Groundwood						
C-N-S Papers	3.3	7.1	5.5	11.2	-	-
Chem-Mechanical	2.5	5.9	4.8	10.6	-	-
Therm-Mechanical	5.2	10.7	4.0	8.8	-	-
Fine Papers	3.3	6.9	4.8	10.6	-	-
B/I Tissue	4.0	8.4	3.7	8.5	-	-
B/I Fine	2.5	5.7	2.5	5.3	-	-

pH for all subcategories shall be [illegible]

Dashes indicate that color removal is not required.

Source: EPA Development Documents

Documents — i.e., pre-engineering cost estimates developed for sample mills — to calculate the *total* cost to the entire industry, or to major sectors of the industry. ADL's task included reviewing and modifying the published data to put all cost estimates on a comparable basis. Below is a brief description of the key points that pertain to these unit cost data as presented in the EPA Development Documents.

1. Industry Categorization

The Development Documents characterized the U.S. pulp and paper industry in terms of various pulping and nonintegrated papermaking process categories. In some instances (e.g., bleached kraft) the categories are further divided into sub-categories. Typical small, medium, and large plant sizes are selected within each of these categories and subcategories to indicate how the scale of operations affects the cost of effluent control. Thus, a range of hypothetical models is obtained which represents typical sizes of individual pulping or papermaking processes. Mills in the industry are then aggregated by these selected pulping and papermaking processes for cost calculations. The detailed rationale for categorization is contained in Section IV of the Development Documents.

Of course, many mills in the industry utilize more than one pulping process and produce more than a single grade of paper or paperboard. These "combination" mills were placed in the process category with the most offensive effluent characteristics.

2. Specified Standards

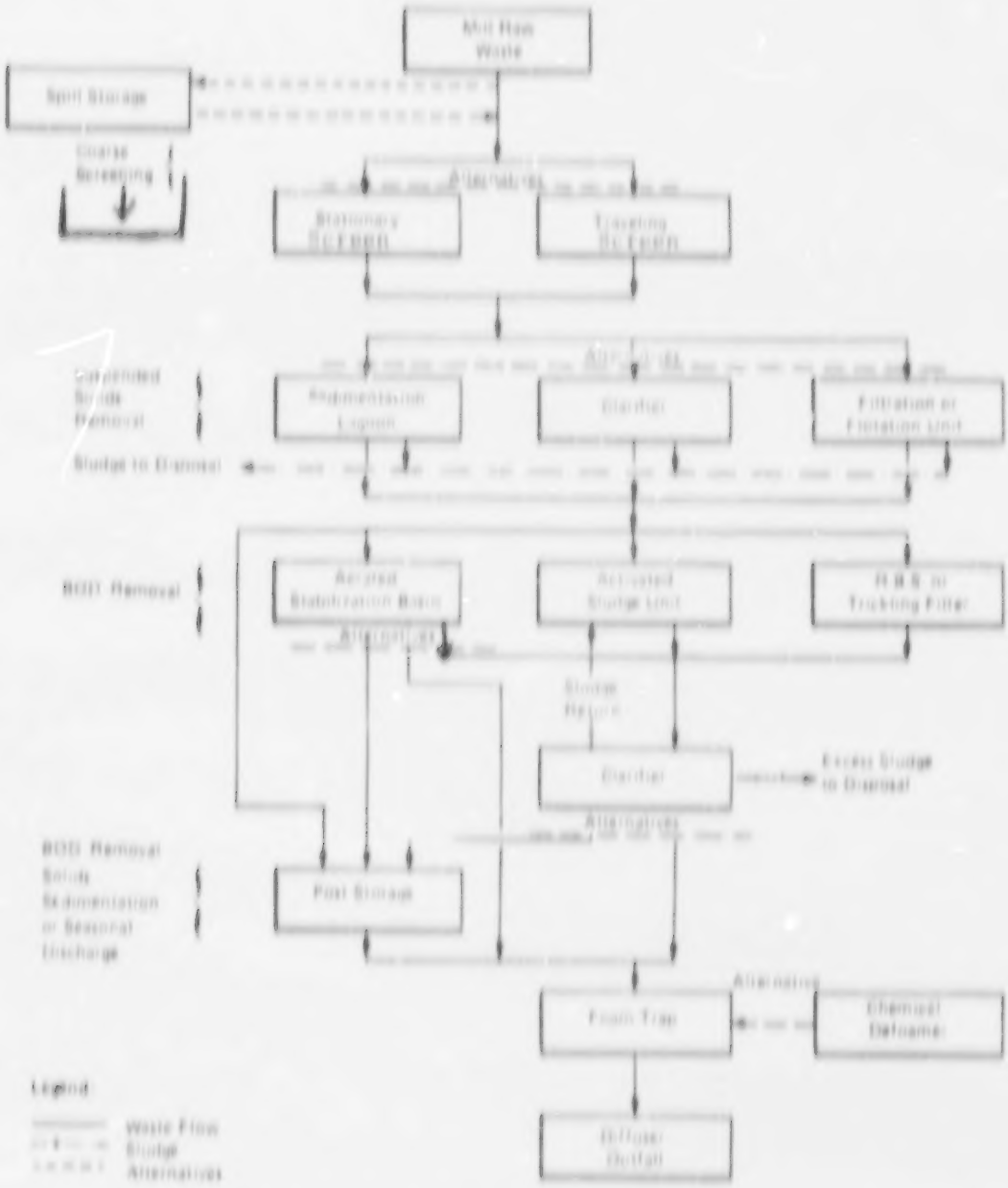
The Development Documents specified the three levels of effluent control previously identified (BPT, BAT, and NSPS). The rationale for selecting the three levels of effluent limitations is presented in Chapters IX through XI of the Development Documents.

3. Treatment Technology

The Development Documents use an engineering approach to specify the effluent control treatment technology; that is, the specifications are based on typical water effluent characteristics including total flow, TSS (total suspended solids), and BOD_5 (five day biological oxygen demand). A "treatment train" is proposed for each subcategory to meet each level of control. Both internal (process modifications) and external ("end of pipe") control measures are used.

In general, the technology selected for BPT and BAT is sequential; that is, BAT can be met by adding items to the treatment train selected for BPT. Primary and secondary treatments with supplementary solids removal are specified to meet the BPT guidelines for all subcategories except nonintegrated fine paper and tissue. Two alternatives, an aerated stabilization basin (ASB) or activated sludge (AS), are included to accomplish secondary treatment.

To achieve BAT guidelines, secondary treatment and media filtration are required for all subcategories, plus minimum lime treatment for color removal in the kraft, NSSC, and soda subcategories. Figure E-1 is a generalized flow diagram for external treatment alternatives as shown in the Development Documents. Internal treatment methods, such as felt hair removal and re-use of vacuum pump seal water, are primarily process modifications that reduce the water effluent load and/or pollutants. These process changes often result in cost savings through economies in materials and/or energy; thus, it is difficult to state unequivocally that a particular item is mainly a process improvement or an effluent control step. In the Development Documents, capital costs for all items listed as internal control technology (except sulfite liquor



Source: Development Document

FIGURE E-1 ALTERNATIVE TREATMENT SYSTEMS

incineration and recovery) were charged to effluent control, however, it was assumed that operation and maintenance charges were offset by material and energy savings. It was assumed that heat and chemical recovery associated with sulfite liquor recovery would pay back the initial investment in sufficiently short time to make the installation attractive; hence, the costs associated with this internal treatment step were not included as part of the treatment costs. A detailed discussion of the various external and internal alternatives is presented in Section VIII of the Development Documents.

4. Cost Models, General

The Development Documents used the cost model approach to develop engineering cost estimates for compliance. Water conditions were postulated for "representative" mills according to plant size and manufacturing process. In most of the subcategories, three sizes of models (small, medium, and large) were specified on the basis of the treatment trains selected.

For each model, cost curves and resultant unit costs were then developed, based on "model" effluent treatment facilities sized for several flow capacities. The Development Documents postulated certain unit processes, yard piping layouts, methods and materials of construction, site and soil characteristics, unit construction costs, and operational practices for each of the "model" treatment facilities. Daily peaking factors were applied in the cost development to account for day-to-day variations in effluent from the "model" mills.

Costs were also estimated separately for treatment trains using an aerated stabilization basin (ASB) or activated sludge (AS) for biological treatment. Although activated sludge typically costs about 50% to 80% more than ASB, some mills may desire or need activated sludge for increased efficiency during cold weather or because insufficient land is available for an ASB.

The cost of land for the treatment facilities or for the disposal of residual solid waste is not included in the estimates. Land requirements for various treatment technologies, however, are tabulated in the Development Document. These requirements are based on sludge disposal to an on-site lagoon for BPT and on dewatering and offsite landfill disposal for BAT.

In some instances, land may not be available for the disposal of sludge. In that event, this sludge would have to be incinerated at the plant site. The cost of this step was not estimated in the Development Documents. ADL "guesstimates" that in those installations requiring incineration, the capital investment requirement would increase by 10-30% of the unit cost.

Both capital and operating costs were estimated for external treatment. Capital costs include the traditional expenditures for such items as mechanical and electrical equipment, instrumentation, yard and process piping, earth-work, unit construction, site preparation and grading, equipment installation and testing, and engineering. However, as stated previously, only capital costs were included for internal process control; direct operating costs were assumed to be offset by savings, so that only the capital-related items — depreciation and cost of capital — were included in the operating costs associated with internal control. Items such as electrical equipment, instrumentation, process piping, site preparation, and engineering were included as a percentage of the base capital costs, which vary for each applicable control technology. A 15% contingency was also included with each control technology to cover miscellaneous work items not included in the estimates.

Operating costs include: (1) operation and maintenance costs, which are "the sum of the annual costs for operating labor, maintenance labor, energy requirements, and chemicals" and (2) depreciation and cost of capital at 15% of total capital. Note that maintenance materials are not included.

5. Cost Models, Existing Mills

The costs for internal and external treatment are shown separately for (1) treatment facilities in place as of the end of 1973, (2) BPT water effluent control, and (3) BAT water effluent control. A different estimating procedure is used for internal and external controls: the cost of *internal treatment* facilities in place is calculated by estimating a percentage of each item which corresponds to the percentage of mills in a category that are presumed to have installed that item by 1973; the cost of *external treatment* facilities in place is calculated by postulating a treatment train that includes some items and excludes others for a typical mill. Thus, the 1973 internal estimates are intended to correspond to a category average, but not necessarily to a typical mill model. Conversely, 1973 external estimates are intended to correspond to a typical mill model.

The estimates of in-place effluent treatment facilities used as the data base in the Development Documents appear to understate the extent of the treatment installed by the paper industry through 1973. For example, no external treatment facilities were assumed to be in place in unbleached kraft, NSSC medium, unbleached kraft/NSSC, recycled paperboard, construction paper, or nonintegrated tissue and fine categories. Actually, most of the mills in these categories already have some level of secondary treatment.

The other process categories were presumed to have only primary treatment. Again, many mills in these other categories already have some degree of biological treatment. Thus, while those mills with secondary treatment may have to modify or supplement their existing facilities to meet the BPT and BAT regulations, in general the basic assumption in the Development Documents regarding the level of in-place facilities tends to overstate the incremental costs to achieve BPT control levels.

About 180 mills are tied into municipal treatment. In general, these are nonintegrated paper or paperboard mills that make tissue, recycled paperboard, or construction paper. The Development Documents assumed that no investment and/or operating costs would be incurred by these mills for waste treatment.

6. Cost Models, New Mills

NSPS guidelines for new mills meet some, but not all, of the BAT control requirements that apply to existing mills. While the *internal* technologies and costs are the same as for BAT, color removal is not required by NSPS as part of the external treatment; hence, the costs are not the same. Note, however, that whereas the listed costs for BPT and BAT are incremental to those of the treatment facilities assumed to be in place through 1974, the cost for NSPS is the *total* cost for internal and external treatment. Hence, the cost for NSPS is greater than the incremental costs for BPT plus BAT, even though the requirements are not as stringent.

Since a 10-year permit is written for a new source, the cost of the transition from NSPS to BAT will not be incurred until after 1986, which is beyond the time period considered in this study.

7. Variability of Cost Models

The model approach is useful in assessing overall industry costs or aggregate costs for subcategories containing a large number of mills. However, in applying the cost estimates to individual mills or small subcategories, one must consider the possible variations in required technology and/or site specific costs. The following comments on cost variability are quoted from the Development Documents:

> "It should be recognized that actual treatment costs vary widely from mill to mill depending upon the design and operation of the production facilities and local conditions. Furthermore, effluent treatment costs reported by the industry vary greatly from one installation to another, depending upon bookkeeping procedures. The estimates of effluent volumes and treatment methods described in this section are intended to represent those of the subcategories covered by this report. However, the industry is extremely heterogeneous, in that almost every installation has some uniqueness which could be of importance in assessing effluent treatment problems and their associated costs.
>
> "It should be remembered that actual external treatment costs may vary significantly from mill to mill, depending upon [...] climate, topography, soil conditions, unit locations, and the design and operation of the particular waste treatment facility."

C. ADJUSTMENT OF THE DATA BASE

1. Industry Categorization

The ascribing of mills to a process category is not a precise analytical exercise. As mentioned, with the exception of kraft with NSSC pulping, each cost model in the Development Documents represented a *single* process; in practice, however, many mills employ more than one pulping or papermaking process. Accordingly, designating a mill as belonging in a certain process category (and hence implicitly in a product sector for economic impact analysis) is somewhat arbitrary.

ADL used the same process categories as those identified in the Development Documents to categorize the industry, but used a somewhat different rationale for assigning mills to those categories. The criteria that were applied in grouping mills by category are described in Appendix B.

2. Revised Standards

Since the unit cost estimates reported in the original Development Documents were prepared, EPA has revised the studied regulations. In general, the overall permissible level of BOD discharge has been increased by about 20-30% and the overall suspended solids discharge increased by about 35-40% beyond the level initially reported and used as the basis for engineering cost estimates. Table E-20 compares the initial and revised BPT regulations for selected process categories. (The revised regulations are contained in the updated Development Document of January 1976.) While the revised regulations are, in some categories, significantly less stringent (particularly with reference to suspended solids removal), the same *unit* costs based upon the more stringent regulations were published in January 1976 by EPA and used by ADL for the revised regulations.

TABLE E-20

COMPARISON OF THE INITIAL AND REVISED BPT
WATER EFFLUENT GUIDELINES FOR SELECTED PROCESS CATEGORIES
(lb/ton)

	Maximum 30-day Average			
	BOD_5 Limit		TSS Limit	
Process Subcategory	Initial	Revised	Initial	Revised
Bleached Kraft				
BCT Kraft	12.7	13.9	20.6	30.2
Fine Kraft	9.4	11.4	14.7	24.8
Dissolving Kraft	25.9	26.7	31.1	38.6
Market Kraft	14.2	15.8	20.6	31.7
Sulfite, Paper Grade	30.4	39.2	42.3	48.0
Dissolving Sulfite (low alpha)	45.4	44.7	52.5	54.8
Soda	11.5	14.4	16.6	26.8
Deinked	14.0	18.9	25.3	28.4
Groundwood				
C-N-S Paper	8.4	8.9	14.0	15.8
Chemi-Mechanical	7.0	14.1	11.8	20.9
Thermo-Mechanical	5.2	10.0	8.9	18.4
Fine Papers	7.5	8.0	12.9	14.6
N/I Tissue Paper	9.4	12.5	9.3	10.0
N/I Fine Paper	8.4	8.5	8.5	11.8

Source: EPA Development Documents

3. Treatment Technology

ADL has not made an in-depth analysis of the methods of treatment specified for achieving the prescribed levels of effluent control. In general, however, as the cost models are based upon treatment methods that are actually used to achieve the prescribed levels of treatment, the specified "treatment trains" appear to be appropriate for deriving cost estimates.

The "model" treatment facilities may prove inadequate or insufficient to meet the prescribed level in certain mill situations. Site- and mill-specific cost estimates are obviously preferable in such cases. Thus, while it is not the intent of either the Development Documents or the industry analysis prepared by ADL to identify and evaluate every site- and process-specific situation, the studies provide (a) a reasonable method of assessing total cost to the industry, and (b) a convenient point of departure for evaluating specific situations that may be at variance with the sample cost models.

4. Cost Models, General

The effluent control cost estimates published in the Development Documents are expressed in second-quarter 1974 dollars. To adjust these to mid-1975 dollars, ADL increased both investment and operating costs by 20%. The increase in investment is significantly higher than that reported in typical engineering cost indices, but specific information on cost increases in the pulp and paper industry indicates that the value ADL used is more appropriate. ADL believes that this would also apply to pollution control equipment at paper mill sites, particularly new mill installations. The increase in operating costs is a weighted average of estimated increases in individual cost items, which range from 10% on labor to 60% on chemicals.

In addition to revising the Development Document cost data to mid-1975 dollars, ADL added the following operating cost items, which were excluded from the Development Document but are (ADL believes) legitimate effluent control operating charges:

- Factory overhead and general administration at 12% of the estimated direct labor cost for pollution abatement. The Development Document operating costs include overhead for direct labor supervision only.
- Professional administration for monitoring and reporting, including relations with regulatory agencies, estimated at an essentially fixed cost of $2,000 per installation, regardless of size or category. The Development Document estimates include the direct costs of measuring, sampling, analysis, and compilation of data.
- Insurance and local property taxes at 1½% of total investment. This figure is somewhat lower than is typical of pulp and paper facilities, and reflects the probability that some level of local property tax relief will be allowed for effluent control installations and process modifications.
- Maintenance materials at 1% of total investment.

The aforementioned refinements did not affect the estimated total capital costs and added about 5% to the annual operating cost estimates given in the Development Documents.

5. Cost Models, Existing Mills

As noted previously, ADL believes that the level of in-place treatment facilities stipulated in the Development Documents and used as the basis for determining incremental costs is grossly

understated. More specifically, the Documents assume no external treatment facilities whatsoever in mills in the unbleached kraft, NSSC medium, unbleached kraft/NSSC medium, and recycled paperboard and construction paper process categories. Production from mills in these categories constitutes about 50% of the entire industry capacity. Furthermore, the Documents assume only primary treatment facilities in place through 1973 in the rest of the industry. ADL believes that both assumptions grossly understate the level of in-place treatment facilities. In ADL's opinion, practically all mills have primary treatment and about one third have some degree of secondary treatment. Thus, while mills with secondary treatment may need to expand and/or supplement existing facilities to achieve BPT regulations, ignoring the existence of such facilities leads to overstating the incremental need for treatment.

For purposes of this study, ADL has modified the reported data base and assumed that the mills in the unbleached kraft, NSSC, unbleached kraft/NSSC, recycled paperboard, and construction paper categories have (at a minimum) primary treatment. Since the capital investment for primary treatment constitutes about 25% of the incremental cost for compliance with BPT, ADL has effectively reduced the investment requirement derived from the cost models appearing in the Development Documents by that amount. Further, since the production from mills in these process categories comprises about 50% of the industry capacity, the total industry's derived cost to meet BPT regulations is reduced by about 12.5% (25% x 50%).

In calculating the investment and operating costs for industry sectors, ADL (like the Development Documents) assumed that no charges were incurred by mills tied into municipal treatment systems. As a result, the aggregate, average cost for the industry sector understates the cost for mills with on-site treatment facilities. To illustrate the range of cost to a particular mill, however, ADL lists the maximum and minimum values.

8. Cost Models, New Mills

Based on industrial practice, ADL selected new mill examples for the various categories that are somewhat different from the "typical" mills in the Development Documents. The effluent control costs for the mill sizes reported in the Development Documents were adjusted to the representative pulp processes. In those cases where the unit size or "typical" size papermaking process is significantly smaller than the pulping operation, the capital and operating costs associated with pulp manufacture are reduced in proportion to the size of the papermaking operation. In this manner, costs of compliance are reported on a finished product basis for subsequent economic analysis but take into account the economies achieved in a larger *pulping* (process) operation.

D. EXISTING INDUSTRY AGGREGATE COST

To develop total investment and operating costs by process category, it is necessary to estimate total capacity by process category. Based on published mill data, year-end 1974 capacity was totaled by category, mill size, and mills known to be on municipal treatment. The assignment of mills to categories is not precise; most large mills are complex, in terms of both products and pulping processes, and they could fit more than one category. To project the capacity of the existing industry to 1977 and 1983, ADL assumed certain capacity retirement rates, based on experience, for each category. This includes tonnage retired due to water effluent pollution regulations, obsolescence, and all other economic or technical reasons. No capacity retirement was assumed among mills using municipal treatment.

In calculating the aggregate costs, ADL specified the following conditions and assumptions:

(1) No additional treatment costs will be incurred by mills already on municipal treatment through BAT. All other mills will use the standard internal and external treatment technologies specified in the Development Documents.

(2) In the unbleached kraft, NSSC, unbleached kraft/NSSC, construction paper, sulfite (paper grade), soda, and groundwood categories, all mills will use ASB biological treatment.

(3) In the recycled paperboard, dissolving sulfite, deinked, nonintegrated tissue, and nonintengrated fine paper categories, 50% of the capacity will use ASB and 50% activated sludge for biological treatment.

For a given category, the costs for BPT and BAT were calculated by size. The average cost per ton by size was multiplied by the corresponding tonnage in that size range. The 1977 and 1983 capacities were used to compute the incremental costs of compliance with BPT and BAT respectively. Table E-21 summarizes the investment and operating cost thus calculated.

Compliance with the BPT requirements will require about $2.3 billion in capital costs for the existing industry as a whole, and annual operating costs will total $250 million. BAT regulations will cost an additional $1.4 billion in capital costs plus $153 million in annual operating costs. Any capital investment for replacement or net new additional capacity that may be built after 1974 is not included, and operating costs exclude depreciation and cost of capital. BPT (1977) costs are incremental from the year-end 1974 level; BAT (1983) costs are incremental from BPT.

As noted previously, the cost of land was not included in the Development Documents. ADL estimates that the cost of land for on site treatment facilities would be about $26 million, or less than 1% of the total capital requirement.

Land availability was cited in the ADL mill closure analysis as a key factor in a mill's ability to comply with the environmental regulations.

If there were indications that a mill would be unable to obtain land for on site effluent treatment, or tie into a municipal sewer, it was classified as a pollution-related closure. (See Chapter V.)

E. NEW MILL UNIT COSTS FOR SELECTED EXAMPLES

Unlike the aggregate cost estimates prepared for the existing industry, aggregate costs for new industry capacity were not derived in this report, because the results of the economic impact analysis influence the amount of the new capacity. Accordingly, it is appropriate to present only the unit cost for selected examples.

The effluent control regulations for NSPS and the estimating procedure for deriving the associated cost of compliance have been described in an earlier section of this Appendix.

TABLE V-21

ESTIMATED WATER EFFLUENT CONTROL COSTS FOR THE PAPERING INDUSTRY BY PROCESS SUBCATEGORIES

Process Subcategory & Size (1/2)	Plant Design Capacity (1/2)	Number of Plants	Total Annual Production (1/2)	Total Annual Water Use (1/2)	Total Annual Effluent Flow (1/2)	Total Annual Pollutant Discharge (1/2)	Total Capital Cost ($ Millions)	Total Annual Cost ($ Millions)	Effluent Control Costs[2] Annual Cost (¢/ton)	Annual Cost (¢/1000 gal)	Capital Cost (¢/ton)	Capital Cost (¢/1000 gal)	Annual Cost/Sales (%)	Capital Cost/Sales (%)
Unbleached Kraft: small														
med.														
large														
Semi-Chem & Recy Fiber: small														
med.														
large														
Unbleached Kraft/Semi-Chem: small														
med.														
large														
Paperboard from Waste Paper: small														
med.														
large														
Builders' Paper & Roofing Felt: small														
med.														
large														
Kraft Board: small														
med.														
large														
Fine Kraft: small														
med.														
large														
Dissolving Kraft: med.														
large														
Market Kraft: small														
med.														
Bulking: med.														
large														
Dissolving Sulfite: large														
Soda: medium														
Deinked: small														
med.														
large														
Groundwood C-N-S: small														
med.														
large														
Chem-Mechanical: small														
med.														
large														
N/S Fibers: very small														
small														
medium														
large														
N/S Rice: small														
medium														
large														
	161	49,000	46,970	48,160	111	1,810	2,111	1,111	159.2	111.0	4.1	4.8	4.7	4.1

Notes: [1] Assumes that none of the capacity on municipal treatment is at risk of 10% would retrofit to steam; no additional tonnage would be tested on a material calculation.

[2] No additional capital or operating costs are included for mills on municipal treatment. Primary treatment assumed to be in place to levy for all existing facilities, with the exception of sedimentation tank and riparian categories, where no treatment is required so as to place.

[3] Abbreviations used in table headings:
TSS (suspended solids); BOD (biochemical oxygen demand); COD (chemical oxygen demand); TOC (total organic carbon); O&M (operation and maintenance); POTW (publicly owned treatment works).

[4] Tonnage treated equals total capacity minus capacity on municipal treatment.

APPENDIX E-3

OSHA NOISE CONTROL

A. CONTROL REGULATIONS

The regulations promulgated for existing industry and new mills by the Occupational Safety and Health Administration primarily concern noise level and personal safety. From the standpoint of cost for compliance, noise far outweighs personal safety. Thus, in examining the cost impact of environmental regulations, ADL has dealt only with the noise aspects of OSHA requirements.

The present regulation (Occupational Safety and Health Act of 1970) imposes restrictions on worker exposure (on a time-weighted basis) to noise levels greater than 90 dBA. It gives preference to the following methods of compliance:

(1) *Engineering controls*, which either reduce the noise at the point of origin or modify the work area so as to reduce the level of noise in that area; and/or

(2) *Administrative controls*, which reduce the worker's exposure to noise by limiting the length of time he is exposed to it.

If these methods, either singly or in combination, are not feasible or fail to achieve the desired degree of noise reduction, a third method may be used:

(3) *Personal protection*, i.e., the use of hearing protective devices. In its practical application, the law has permitted the use of personal protective devices more freely than the above would imply.

OSHA proposed various revisions to the 1970 law in the Federal Register of October 24, 1974. In essence, these call for the following:

(1) Maximum feasible use of engineering and administrative controls before supplementation by personal protective devices;

(2) A hearing conservation program, which would include audiometric testing of all production workers exposed to noise levels above 85 dBA;

(3) Monitoring of the sound levels in working areas and measurement of the exposure of individuals exposed to a time-weighted average of 85 dBA or more;

(4) Maintenance of records for (3) above and for calibration of the instruments used.

For purposes of this analysis, ADL examined the cost of compliance with the proposed regulations.

B. COST OF COMPLIANCE

1. Introduction

The main operating areas and functions in an integrated pulp and paper mill that are characterized by high noise levels include the following:

(1) Wood Room

- chipper
- wood and chip unloading

(2) Pulp Mill

- washer
- screening and cleaning
- bleach plant

(3) Paper Mill

- refiner room
- "broker" beater
- paper machine (wet end and dry end)
- winder

(4) Coating and Finishing

- coater
- finishing (converting)

(5) Auxiliary

- power boiler and turbine room
- recovery boiler

Obviously, not all integrated pulp and paper mills have all of these functions, and some use equipment with even higher noise levels (e.g., a debarking drum in the wood room). Furthermore, many mills have more than one paper and/or board machine to a single wood room and pulp mill. Hence, estimating the cost of bringing one facility to a permissible noise level or protecting a single production worker from overexposure is a complex, site-specific task, particularly when it is recognized that compliance may be achieved by more than one method.

Since neither the present nor the proposed standards specify a desired ratio of engineering to administrative controls, the associated costs are arbitrary and subject to considerable variation, not only from plant to plant but even within each process step.

In view of the complexity of the problem and the numerous alternatives that one can select to bring a facility into compliance, it is not surprising that cost estimates are judgmental and that different sources vary widely.

2. Existing Industry, Aggregate Costs

ADL was not retained to develop engineering cost estimates for compliance with OSHA noise regulations; instead, it relied upon available sources. The following two sources deal with these cost estimates:

- A study[1] prepared by Bolt, Beranek & Newman Inc., (BBN) for the U.S. Department of Labor; and
- Correspondence between ADL and the American Paper Institute (API).

After reviewing these documents, ADL elected to adjust and use the API estimate (see Section III-F-2). In a study that it made in 1974, the API estimated that the cost of compliance with a 90-dBA level would be about $2 million (expressed in 1975 dollars) for an existing 500-tpd integrated pulp and paper mill. The estimate assumes that compliance would be achieved by reduction of noise "in the workplace." Accordingly, the estimate includes costs for relocating instruments and controls associated with each of the process steps previously identified.

More recently, API conducted a company survey and estimated that the existing industry would have to invest some $516 million to comply with the proposed 90-dBA regulation. This figure, which does not include the cost of facilities already in place, applies to all sectors within the 2000 SIC code — pulp, paper, and board manufacturing and converting.

Since the present study did not include converting nor the manufacture of certain types of building products (e.g., hardboard and particleboard), the full $516 million did not apply. Keeping in mind that the excluded sectors had fewer than the average number of workers and process steps per mill, ADL assumed that they would incur 25% of the total investment. The remainder, about $400 million, was applicable to the studied sectors.

To allocate this incremental $400 million into various process categories, ADL took the position that the capital costs for compliance are more closely related to type and number of installations than to the number of production workers. It was first estimated that the investment for compliance by an integrated pulp and paper mill would be about three times that of a nonintegrated paper or board mill. Since there are about 100 integrated mills and 200 nonintegrated mills, the incremental cost per mill was calculated as follows:

$$100(3x) + 200x = \$400 \times 10^6$$

$$x = \$1{,}000{,}000 \text{ for a nonintegrated mill}$$

$$3x = \$3 \text{ million for an integrated mill}$$

In this study, ADL assumed that 80% of these expenditures would be required through 1977 and the remainder between 1977 and 1983. As with the studied air and water regulations, costs associated with new mills were handled separately.

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1 "Economic Impact Analysis of Proposed Noise Control Regulation," Report No. 3048, Contract No. HSM-J-5-F-5-0018, April 21, 1976.

With regard to operating costs, API has estimated $25-$68 and $20-$40 per worker for monitoring and audiometric testing respectively. ADL used the low end of the range — $25 per production worker for monitoring and $20 per production worker for audiometric testing. In addition to these charges, ADL assumed 5% of capital investment for maintenance labor and supplies and 12.09% for capital recovery.

3. New Mills, Unit Costs

The new-mill cost models developed by ADL were based primarily on an 800-tpd bleached kraft pulp mill, with a single paper machine for a given product (Appendix F). Lacking any information regarding cost for compliance with OSHA noise regulations for new mills, ADL adjusted the capital cost for the 500-tpd existing integrated pulp and paper mill model developed by API (mentioned previously) to $3 million for the larger size and to reflect ADL's opinion that, presented with the option of using either administrative controls or building sufficient "engineering control" into a new mill to comply with noise regulations, a producer would elect to take the latter route. Although administrative control is a much less capital-intensive method of compliance, it is subject to subsequent modification by OSHA in the event the mill is found to be in violation. Rather than risk being faced with the high costs of mill modification, most producers would choose to equip their new mills with adequate "engineering controls" initially. Of the $3 million for OSHA noise control, ADL further assumed that $2 million applied to the pulp mill and the remaining $1 million to each paper/board machine, because more process steps are involved in the pulping process. Also, operating costs of $110,000 per year were included for maintenance, record keeping, monitoring of sound levels, audiometric testing of workers, and calibration of instruments. Operating costs for small, nonintegrated recycled paper mills were assumed to be slightly lower ($70,000 per year).

These capital and operating costs are order-of-magnitude only.

APPENDIX E-4

COMPARISON AND DISCUSSION OF PUBLISHED COSTS OF COMPLIANCE WITH ENVIRONMENTAL CONTROLS

There are few published estimates on costs of compliance with the studied air, water, and OSHA noise regulations. For purposes of this discussion, the costs were divided into two discrete areas: (1) costs associated with air and water controls, and (2) cost of compliance for OSHA noise control. Below is a detailed discussion on each area.

In its report to API,[1] URS Research Company cited the costs of compliance with the studied air and water regulations which were initially estimated by Hazen & Sawyer and NCASI respectively. Both original sources developed (or reported) estimates for the existing industry. The costs of compliance for new capacity built during the studied period were estimated at 15% of production-related capital requirements. Table E-22 summarizes the costs reported in the URS report and compares them with those given in this report.

For the period of 1974 to 1983, URS reported $8.7 billion capital requirements for both water and air controls, while ADL estimated $6.6 billion, some $2.1 billion less than URS. These estimates include costs for both existing industry and new and replacement capacity. The more in-depth comparisons on air and water control are made separately below, since they come from different sources.

A. AIR EMISSION CONTROL COSTS

ADL/EPA and URS/NCASI disagree significantly on the cost to the existing industry for compliance with air regulations, particularly for the 1978-1983 period. Since the URS report contains no information to support the estimates or to explain the methodology used in deriving them, ADL cannot be sure of the reasons for its variances. They appear to be the assumptions (hence related costs) associated with:

- required level of control for the existing industry, and
- capitalized maintenance and replacement of capacity.

NCASI obtained information on the existing industry by a mill survey, estimated the costs for the 1974 to 1977 period, and extrapolated them to the 1978 to 1983 period. ADL derived its estimates empirically from the costs associated with each major segment of the industry. The reasonableness of the result was assessed by comparing it with the reported industry survey estimate after making allowances for costs reported separately in the ADL cost analysis. ADL staff also discussed the estimates reported by URS with NCASI representatives and thereby obtained a verbal description of the methodology that URS used.

Implicit in the mill/company survey approach is the difficulty of differentiating between investment requirements for replacement and/or incremental expansion on the one hand and costs associated with environmental regulations on the other. Typically, when a mill or company

1. "The Economic Impacts on the American Paper Industry of Pollution Control Costs." Report by URS Research Company to the American Paper Institute, September 1979.

TABLE V-21

SUMMARY COMPARISON OF IRS AND ADL COST OF COMPLIANCE ESTIMATES
(Capital investment reported in mid-1975 dollars)

Reporting Period (year-end)	IRS Capacity Period-end (Million Tons)	IRS Capital Investment[a] ($Billion) Air	IRS Capital Investment[a] ($Billion) Water	IRS Capital Investment[a] ($Billion) Total	ADL Capacity Period-end (Million Tons)	ADL Capital Investment ($Billion) Air	ADL Capital Investment ($Billion) Water	ADL Capital Investment ($Billion) Total
1974 - 1977								
Existing Industry	68	1.0	2.2[c]	3.2	67	0.7	1.2	1.9
New Plus Replacement Capacity	5	---Not Shown---			5	Air & Water combined		0.5
Total Period	73[b]	1.0	2.2	3.2	72[d]	Not applicable	Not Applicable	2.4
1974 - 1983								
Existing Industry	66[e]	2.4	3.9	6.3	65[e]	2.9	1.6	4.5
New Plus Replacement Capacity	7[f]	Air & Water Combined		2.4	7[f]	Air & Water combined		2.3
Total Period	89[b]	Not Applicable	Not Applicable	8.7	86[d]	Not applicable	Not applicable	6.8

[a] IRS reported costs in 1974 dollars, which ADL converted to mid-1975 dollars using a factor of 1.2

[b] IRS reported total year-end capacity of 74 and 92 million tons for 1978 and 1984 respectively. ADL adjusted to 73 and 89 million year-end capacity tons to reflect capacities for 1977 and 1983 respectively.

[c] Water control costs account for 49 million tons as reported by Hazen & Sawyer, Inc.

[d] Capacity estimates reported by API - Paper, Paperboard, Wood Pulp Capacity 1974-1977, October 1975, pp. 13-17.

[e] IRS and ADL both assumed retirement of about 2 million tons from year-end 1977 to 1983.

[f] Corresponds to "medium growth" for the industry based upon Chase Econometric Forecast Model. (Note low an. "high growth estimates corresponded to 82 and 89 million tons respectively.)

makes a major capital expenditure, it includes provisions for replacing obsolete equipment, increasing capacity, and environmental control. The apportionment of the capital budget into these categories is inherently qualitative and arbitrary. Hence, without implying any covert motives to the respondents of the NCASI survey, there is an inherent imprecision in information derived via industry survey for cost analysis. For the above reason, AID, derived its estimates empirically and thereby gained some insight regarding possible areas of cost variances. The key areas described below may have contributed to the variances between the two estimates.

1. Level of Control

State Air Quality Implementation Plan (SIP) standards apply to the existing industry; federal regulations do not. Further, SIP requirements vary significantly from state to state; hence, a given type and size of mill can have greatly different costs of compliance, depending on its location.

Even though many states presently do not have regulations as stringent as those of Oregon, AID, used that state's SIP standards (which require 99% particulate recovery) to calculate the existing industry's cost of compliance. AID, assumed that state regulations would not become progressively stringent over the time period to 1983, but rather, that the current Oregon state regulations would be more broadly applied to those states that presently have less stringent regulations. However, if the SIP regulations were to become as stringent as the new source standards, an additional $1.4 billion would be required to bring the industry from SIP's to new source control level. This would reduce the difference between the cost estimates significantly.

The EPA (NCASI) estimates did not specify what regulations were used in deriving the cost estimates or whether more stringent controls — beyond those assumed through 1977 — would apply in the 1978 to 1983 period. Judging from its magnitude, however, one would suspect that the estimate for the existing industry's expenditures from 1978 to 1983 includes provision for the application of more stringent regulations.

2. Capitalized Maintenance/Replacement Cost

Major capital expenditures are occasionally budgeted entirely for environmental controls. More frequently, however, they are primarily for the building of grassroots facilities, replacement of existing capacity (capitalized maintenance), or incremental expansion of existing mills, and only a portion of the investment goes into environmental control. Unfortunately, it is difficult to generalize on the amount that is necessary for compliance with environmental regulations in relation to the expenditures for enlarging capacity or increasing the efficiency of the process.

On the basis of reported historical data, AID, made a rough estimate of capitalized maintenance as a percentage of reported total capital expenditures. This was done by subtracting the reported amounts spent for environmental controls and incremental expansion (based on an average replacement value) from the total capital expenditures reported by the industry. Thus calculated, capitalized maintenance amounts to only 0.67% of the total, which is unrealistically low. It indicates that the reported historical capital expenditures for environmental controls include some capitalized maintenance charges. This is not to imply intentional misrepresentation of the allocation of reported capital budgets as much as to acknowledge the inherent difficulty and judgmental nature of the allocating procedure.

For cost estimating purposes, ADL has shown separately the capital investment associated with:

- capitalized maintenance to maintain the existing industry at rated capacity; and
- investment requirements for new capacity, regardless of whether that new capacity is to replace existing capacity or add net additional capacity.

Hence, by deriving the cost of compliance empirically, ADL has attempted to avoid the inappropriate allocation of industry expenditures.

Table III-6 (see Chapter III) summarizes the derived capital cost for air emission control for the existing industry using the Oregon SIP standards. The estimate of $1.3 billion includes costs for (a) those mills using the kraft process, (b) power boiler controls for other process categories, and (c) earlier retirement of recovery boilers in the kraft process categories. As stated, these costs were derived empirically. The methodology and supporting data are included in Appendix E-1 of this report.

Deducting the reported industry expenditure of some $0.4 billion from the derived estimate results in an incremental cost of $0.9 billion in additional capital for the existing industry to achieve the 99.0% particulate recovery required by the Oregon stan...[2] Obviously, if more rigid standards were postulated, the incremental cost would be significantly higher.

By way of comparison, the incremental air emission control cost reported by NCASI (Table E-22) for the existing industry amounts to some $2.4 billion (mid-1975 dollars). On the assumption that perhaps 85% of this total is associated with the kraft process, the resultant $2.0 billion corresponds to some $16 million for *each* of the 127 existing kraft mills in the industry. This figure appears to be much too high for the incremental cost of compliance; it must include provision for other capital requirements, such as incremental new capacity or capitalized maintenance items, which are shown separately in the ADL cost analysis.

B. WATER EFFLUENT CONTROL COSTS

1. Summary

Few studies have been made of the capabilities and cost of technology used by the pulp and paper industry to meet the requirements of the Federal Water Pollution Control Act Amendments of 1972. They include the report by Hazen & Sawyer, Inc. (H&S) to the National Commission on Water Quality, EPA Development Documents, and the MRI study that ADL is presently undertaking for EPA. Both H&S and the Development Documents estimated the costs of various options for achieving pollution abatement levels on a "cost-model" basis, but only H&S aggregated the costs to the existing industry to achieve the 1977 (BPT) effluent limitations. ADL has modified and used the unit costs derived in the Development Documents to estimate the aggregate costs to the existing industry for compliance with BPT and BAT regulations.

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2 This estimate does not include capital expenditures for fuel conversion. The conversion of power boilers from oil to coal or from natural gas to oil or coal would add significantly to the derived cost.

For the existing industry to be in compliance with BPT in 1977, H&S estimated a capital cost of $2.03 billion (in mid-1973 dollars); this amount, which included land costs and annual operating and maintenance costs of $104 million, was in addition to that spent as of the end of 1972. When adjusted to a base comparable to ADL's (i.e., after subtracting the cost of land and investment in 1973 and 1974, and converting to 1975 dollars), these figures correspond to $1.10 billion and $140 million respectively (Table E-23). ADL estimated these incremental costs (in 1975 dollars) at $2.25 billion for capital (excluding land costs[1] and $250 million for annual operating and maintenance in 1974-1977.

On the basis used in Table E-23, the capital requirements estimated by H&S and ADL differ by less than 2%; however, the methodologies that were used differed considerably with respect to:

- scope
- basic engineering cost estimates, and
- the methodology used in calculating the aggregate costs

The water effluent guidelines stated in the H&S report are more stringent than those in the EPA Development Documents. H&S also stated that the technology for BPT described in the EPA Development Documents cannot achieve compliance with the proposed guidelines and therefore assumed the addition of mixed-media filters in a third of the integrated pulp and paper mills; hence, its basic engineering costs for the entire treatment train are higher than those used in the Development Documents. However, as stated in Appendix E-2, the average costs for in-place treatment facilities used in the Development Documents are low; this fact increases the incremental costs that appear there. Coincidentally, they are comparable to those of H&S in an aggregate manner.

With regard to operating and maintenance costs, the chief reason for the great variance is the different way in which costs and savings associated with in-process changes are ascribed to plant improvement versus pollution control.

A more detailed discussion of the variance in each of the areas mentioned above follows.

2. Scope

H&S accounted for a total 598 mills, corresponding to the 1972 year-end industrial capacity of some 69 million tons; this included all paper, paperboard, sulfite pulp, and bleached market pulp except wet machine board and construction paper and board.

ADL, on the other hand, accounts for a total of 561 mills, corresponding to a 1974 year-end industrial capacity of 68 million tons. This includes all paper, paperboard, sulfite pulp, and bleached market pulp except special industrial paper, construction board, and wet machine board.

1 Land costs would have added approximately $25 million to the capital costs estimated by ADL.

TABLE E-21

COMPARISON OF WATER EFFLUENT CONTROL COSTS FOR EXISTING INDUSTRY FOR BPT DEVELOPED BY HAZEN & SAWYER AND ADL
(1975 dollars)

	Hazen & Sawyer[a]	ADL
CAPITAL ($Million)		
Total incremental from end of 1972	2,740	*
Land included	20	*
Total incremental from end of 1972, less land	2,720	*
Total spent in 1973 and 1974[b]	530	*
Total incremental from end of 1974	2,190	2,250
OPERATING & MAINTENANCE ($Million/yr)		
Total incremental from end of 1972	140.6	
Total incremental from end of 1974		250.2

[a] Hazen & Sawyer reported the costs in mid-1973 dollars. ADL escalated them to mid-1975 dollars, using a factor of 1.35.

[b] Costs reported in NCASI Special Report No. 76-05 are escalated to mid-1975 dollars.

3. Engineering Cost Estimates

The basic source used by ADL for water effluent control cost estimates is the Development Documents. Below is a comparison of this source with the H&S study.

a. Subcategorization

H&S developed water effluent control costs for 14 process subcategories, excluding construction paper and board. The Development Documents divided the industry into 22 process subcategories.

b. Water Pollution Abatement Levels

H&S selected five pollution abatement levels for existing mills. Level I was described as achieved by the technology proposed by EPA for BPT but does not meet the BPT effluent limitations. Level II is equivalent to BPT. Level III is that which is judged necessary to comply with the EPA limitations promulgated or under consideration for 1983; it is equivalent to BAT as suggested by EPA, except for color removal. Level IV is equivalent to Level III plus color removal. Level V reflects the application of economically and environmentally feasible technological alternatives that are available or likely to become available in the foreseeable future and could approach or achieve elimination of the discharge of all pollutants.

The Development Documents promulgated three pollution abatement levels — BPT for 1977, BAT for 1983, and NSPS. NSPS limitations are less stringent than those of BAT.

The Level II, Level IV, and NSPS specified by H&S appear to be more stringent than the BPT, BAT, and NSPS promulgated by EPA Development Documents. Tables E-24, -25, and -26 compare these guidelines for selected process categories.

c. Approach

Both sources estimated costs on the basis of average waste water effluent characteristics.

Hazen & Sawyer developed the costs for total treatment trains to achieve various levels of control and then adjusted these costs to reflect the existing treatment facilities, first for primary treatment and then for secondary treatment. Since it used a building block approach in going from one level to the other, it obtained considerable flexibility and could postulate many options.

The Development Documents estimated the incremental costs for each subcategory based on the average effluent treatment facilities in place as of 1973. Two sets of costs — one for an aerated stabilization basin (ASB) and the other for activated sludge (AS) — were developed, giving the user a choice between the two.

d. External Treatment Technology

To arrive at Level I, H&S selected two alternatives for the integrated pulp and paper subcategories — ASB or AS. For the nonintegrated subcategories, it used either dissolved air flotation or coagulation/clarification. To meet the BPT (Level II) guidelines, H&S added mixed-media filters to a third of the mills in all the integrated pulp and paper subcategories. Level II' was accomplished by adding mixed-media filters in the rest of the industry and using in-process effluent reduction technology. Level IV was achieved by minimum lime treatment, maximum lime treatment, microlime plus activated carbon, or ultrafiltration in addition to Level III

TABLE E-2A

COMPARISON OF THE BPT WATER EFFLUENT GUIDELINES USED BY HAZEN & SAWYER INC. AND REVISED BY EPA FOR SELECTED PROCESS CATEGORIES

Process Subcategory	Maximum 30-day Average BOD_5 (lb/ton) Limit		Maximum 30-day Average TSS (lb/ton) Limit	
	H&S	EPA Revised	H&S	EPA Revised
Bleached Kraft				
BCT Kraft	9.0	13.9	21.2	30.2
Fine Kraft	9.0	11.4	21.2	24.8
Dissolving Kraft	16.0	26.7	21.2	38.6
Market Kraft	16.0	15.8	21.2	31.7
Sulfite, Paper Grade	36.5	19.2	17.9	48.0
Dissolving Sulfites (low alpha)	53.0	44.7	17.9	54.8
Soda	14.2	14.4	38.0	26.8
Deinked	10.9	18.9	26.0	28.4
Groundwood				
C-M-N Paper	8.2	8.9	14.9	15.8
Chemi-Mechanical	16.0	14.1	14.9	20.9
Thermo-Mechanical	8.2	10.0	14.9	18.4
Fine Papers	8.2	8.0	14.9	14.5
N/I Tissue	8.0	12.5	7.4	10.0
N/I Fine Paper	6.8	8.5	9.4	11.8

Sources: EPA Development Documents & Hazen & Sawyer Report

TABLE E-23

COMPARISON OF THE BAT WATER EFFLUENT GUIDELINES USED BY HAZEN & SAWYER INC. AND REVISED BY EPA FOR SELECTED PROCESS CATEGORIES

	Maximum 30-day Average					
	BOD_5 (lb/ton) Limit		TSS (lb/ton) Limit		Color (lb/ton)	
Process Subcategory	H&S	EPA Revised	H&S	EPA Revised	H&S	EPA Revised
Bleached Kraft						
NCT Kraft	3.2	6.0	5.4	4.1	202	130
Fine Kraft	3.2	5.1	5.4	3.5	202	130
Dissolving Kraft	5.8	11.6	5.4	7.9	202	250
Market Kraft	5.8	7.1	5.4	5.2	202	190
Sulfite, Paper Grade	7.0	17.8	5.8	6.0	-	-
Dissolving Sulfite (low alpha)	10.4	20.1	-	6.9	-	-
Soda	4.4	5.1	6.7	3.5	202	130
Deinked	5.0	5.2	6.6	5.4	-	-
Groundwood						
C-M-N Paper	2.8	3.7	3.3	2.9	-	-
Chemi-Mechanical	5.4	7.8	3.3	3.3	-	-
Thermo-Mechanical	2.8	4.2	3.3	2.9	-	-
Fine Papers	2.8	3.5	3.3	2.7	-	-
N/I Tissue Paper	1.9	4.3	3.2	2.2	-	-
N/I Fine Paper	1.2	2.7	1.9	1.4	-	-

Sources: EPA Development Documents & Hazen & Sawyer Report

TABLE E-16

COMPARISON OF NSPA WATER EFFLUENT GUIDELINES USED BY HAZEN & SAWYER INC. AND REVISED BY EPA FOR SELECTED PROCESS CATEGORIES

Process Subcategory	Maximum 30-day Average BOD_5 (lb/ton) Limit		Maximum 30-day Average TSS (lb/ton) Limit	
	H&S	EPA Revised	H&S	EPA Revised
Bleached Kraft				
BCT Kraft	1.2	7.5	5.4	5.0
Fine Kraft	1.2	5.1	5.4	7.5
Dissolving Kraft	5.8	12.2	5.4	16.7
Market Kraft	5.8	5.3	5.4	5.0
Sulfite, Paper Grade	7.0	9.3	5.8	5.8
Dissolving Sulfite (low alpha)	10.6	22.3	-	20.0
Soda	4.5	6.3	6.7	8.6
Deinked	5.0	7.8	6.6	8.0
Groundwood				
C-M-N Paper	2.8	4.0	3.3	6.3
Chemi-Mechanical	5.4	7.8	3.3	6.6
Thermo-Mechanical	2.8	4.6	3.3	6.3
Fine Papers	2.8	3.8	3.3	6.0
N/I Tissue Paper	1.9	4.3	3.2	4.4
N/I Fine Paper	1.2	2.7	1.9	2.8

Sources: EPA Development Documents & Hazen & Sawyer Report

treatment in bleached kraft and soda subcategories; minimum lime treatment was specified in the unbleached kraft, NSSC, and unbleached kraft/NSSC subcategories. Level V was reached by supplementing Level IV with activated carbon in all subcategories.

The Development Documents proposed a specific "treatment train" for each subcategory. In general, primary and secondary treatments with supplementary solids removal were specified to meet the BPT guidelines for all subcategories except nonintegrated fine paper and tissue. Secondary treatment included ASB or AS. To achieve BAT guidelines, secondary treatment and media filtration were required for all subcategories, plus minimum lime treatment for color removal in the appropriate subcategories. The technology for complying with NSPS would be similar to that for BAT, except that minimum lime treatment would not be needed.

e. Internal Treatment Technology

In general, the internal treatment technologies used in both studies are quite similar, although both sources acknowledge that they are not necessarily the most widely accepted by the industry, nor the most cost-effective. Internal treatment items are primarily process modifications, which often result in cost savings through economies in materials and/or energy; thus, it is difficult to state unequivocally that a particular item is mainly a process improvement or an effluent control step. In the Development Documents, capital costs for all items listed as internal control technology[4] were charged to effluent control, but it was assumed that operation and maintenance charges were offset by material and energy savings. On the other hand, H&S showed net savings for all subcategories except dissolving sulfite.

f. Water Effluent Control Costs

According to their selected technologies, H&S and EPA developed water effluent control costs for each subcategory for the levels described previously. Operation and maintenance costs developed by H&S did not include fixed charges — cost of money, depreciation, insurance, taxes, etc.; the Development Documents included depreciation and interest at 15% of capital expenditure but omitted factory overhead and general administration, professional administration for monitoring and reporting, insurance, local property taxes, and maintenance materials.

Table E-27 compares the investment and operating cost estimates for water effluent control from both studies by the use of selected examples. Note that the variance of the costs based on similar technology (e.g., Level I of H&S and BPT of the Development Documents for unbleached kraft) is within the precision of engineering estimates. However, the *total* cost of *Level I plus Level II*, which the H&S study reports will be required to meet BPT, is in all cases significantly higher than the EPA estimate.

The possible reasons for such variances are:

- the different technology required to achieve compliance; e.g., the inclusion of mixed media filters for a third of integrated mills to meet BPT requirements, and different internal treatment specified in the nonintegrated fine paper subcategory — see Table E-28;
- the different apportionment of costs and savings associated with in-process changes between plant improvements and pollution control.

4 Except sulfite liquor incineration and recovery.

TABLE V-27

COMPARISON OF INVESTMENT AND OPERATING COST ESTIMATES FOR WATER EFFLUENT CONTROL
(SELECTED EXAMPLES)

Basis: - All estimates reported in mid-1971 dollars
- Comparison for existing mills
- All costs are incremental
- Assumes existing mills have no external treatment

Process Sector	Mill Size (tpd)	Level of Control	Source: Kaiser & Gaeger[1] Investment ($MillionS) Internal	External	Total	Operating Cost ($/Ton) O&M	Dep. & Int.	Total	Source: EPA Development Document Investment ($MillionS) Internal	External	Total	Operating Cost ($/Ton) O&M	Dep. & Int.	Total
1. Unbleached Kraft (Aerated Stabilization Basin)	1700	Level I[2]	3.15	9.76	12.91	1.80		1.80						
		Level II[2]	–	2.56	2.56	0.31		0.31		NOT APPLICABLE				
		TOTAL BPT	3.15	12.35	15.50	2.11		2.11	3.76	9.44	13.20	1.4	4.35	5.75
		Level III[2]	–	0.79	0.79	0.33		0.33						
		Level IV[2]	–	4.27	4.27	0.79		0.79		NOT APPLICABLE				
		TOTAL BAT	–	5.06	5.06	0.69		0.69	2.79	3.59	5.40	1.45	1.81	3.26
2. Unbleached Kraft (Activated Sludge)	1300	Level I[3]	3.15	14.29	17.44	1.84		1.84						
		Level II[3]	–	2.58	2.58	0.32		0.32		NOT APPLICABLE				
		TOTAL BPT	3.15	16.88	20.03	1.96		1.96	3.76	11.91	15.67	1.65	5.37	7.02
		Level III[3]	–	0.94	0.94	0.34		0.34						
		Level IV[3]	–	4.27	4.27	0.79		0.79		NOT APPLICABLE				
		TOTAL BAT	–	5.21	5.21	0.95		0.95	2.79	3.59	5.40	0.59	1.81	2.40
3. Dissolving Sulfite (Aerated Stabilization Basin)	600	Level I[2]	3.71	15.41	19.12	6.79		6.79						
		Level II[2]	–	3.45	3.44	0.65		0.65		NOT APPLICABLE				
		TOTAL BPT	3.71	18.85	22.56	7.43		7.43	0.82	27.79	28.21	7.65	23.34	31.07
		Level III[2]	–	1.89	1.89	0.60		0.60						
		Level IV[2]	–	–	–	–		–		NOT APPLICABLE				
		TOTAL BAT	–	1.89	1.89	0.60		0.60	2.55	3.45	5.84	2.80	4.58	6.98

TABLE 6-27 (Cont'd)

Process Sector	Mill Size (tpd)	Level of Control	Source: Bauer & Sawyer[2] Investment: Internal	Investment: External	Investment: Total	Operating Cost (1/Ton): O&M	Operating Cost (1/Ton): Dep & Int	Operating Cost (1/Ton): Total	Source: EPA Development Document: Investment: Internal	Investment: External	Investment: Total	Operating Cost (1/Ton): O&M	Operating Cost (1/Ton): Dep & Int	Operating Cost (1/Ton): Total
4. Dissolving Sulfite (Activated Sludge)	400	Level I[3]	1.71	29.20	30.91	11.97		11.97						
		Level II[3]	–	3.44	3.44	0.65		0.65						
		TOTAL BPT	1.71	32.64	35.35	12.62		12.62	0.42	21.89	22.31	9.61	24.32	33.93
		Level III[3]	–	3.60	3.60	1.12		1.12						
		Level IV[3]	–	–	–	–		–						
		TOTAL BAT	–	3.60	3.60	1.12		1.12	2.38	3.46	5.84	2.80	4.28	6.98
5. Unintegrated Fine[4] Paper	100	Level I[5]	0.11	1.93	2.04	5.07		5.07						
		Level II	–	–	–	–		–						
		TOTAL BPT	0.11	1.93	2.04	5.07		5.07	0.42	1.39	1.81	1.39	4.91	11.31
		Level III[5]	0.56	0.30	0.86	(7.08)		(7.08)						
		Level IV	–	–	–	–		–						
		TOTAL BAT	0.56	0.30	0.86	(7.08)		(7.08)	0.34	0.84	0.80	2.22	5.40	5.07

FOOTNOTES: ( ) Denotes Savings

[2] Bauer & Sawyer has reported the costs in mid-1977 dollars. All escalated them to mid-1976 dollars using a factor of 1.035.

[3] Treatment Options I-1, II-1, III-1 and IV-1a as specified by Bauer & Sawyer, are used as the specified technology is comparable to that of the EPA Development Document.

[4] Treatment Options I-2, II-2, III-2 and IV-1b as specified by Bauer & Sawyer are used as this specified technology is comparable to that of the EPA Development Document.

[5] Different effluent treatment provisions are employed by the two sources (See Table 6-25).

[6] Treatment Options I-1 and III-1 as specified by Bauer & Sawyer are used.

TABLE V-29

EFFLUENT TREATMENT TECHNOLOGY FOR UNCOATED FINE PAPER MANUFACTURE
USED BY NSPS & BAT/BCT AND EPA DEVELOPMENT DOCUMENTS

Effluent Treatment Technology	Source:	NSPS		BAT/BCT		EID *		EPA Development Document	
	Treatment Level:	I		III		II		BPT	BAT
	Option:	I - 3	I - 4	III-3	III-4	II - 3	II - 4		
Internal Technology Items									
1. Internal spill containment		x	x	x	x	x	x		
2. In-process effluent containment (stock preparation & paper machine effluent collection & treatment)				x	x	x	x		
3. Alarms at critical tanks								x	x
4. Paper machine isolation sewers								x	x
5. Paper machine high pressure showers								x	x
6. Cooling water segregation & reuse									x
7. Felt bath removal								x	x
8. Vacuum pump seal water reuse								x	x
9. Paper mill stock spill collection system									x
External Technology Process									
1. Preliminary		x	x	x	x	x	x	x	x
2. Pump station		x	x	x	x	x	x	x	x
3. Primary Clarifier			x		x		x	x	x
4. Sludge Lagoon								x	x
5. Aerators									x
6. Aerated stabilization basin									x
7. Vacuum filters									x
8. Aeration		x	x	x	x	x	x	x	x
9. Outfall								x	x
10. Effluent		x	x	x	x	x	x	x	x
11. Black liquor lagoon								x	x
12. Mixed media filtration								x	x
13. Dissolved air flotation				x	x	x	x	x	x
14. Activated [illegible]		x		x		x			
						x	x		

* EID - Elimination of Pollutant Discharge

Recall that these unit costs are for the *entire* (internal plus external) treatment facility without any deduction for in-place facilities through 1974. Because EPA understates the level of in-place treatment facilities through 1974, a larger *net increment* of capital is required to meet BPT regulations.

Both H&S and the Development Documents tabulated land requirements for each external waste water treatment component, but only H&S calculated the attendant costs. These were based on $[illegible]/acre for AS, $[illegible]/acre for ASB, and $20,000/acre for dissolved air flotation or coagulation/clarification.

Arthur D. Little has used the Development Document unit cost estimates with certain adjustments, namely:

- Conversion from mid-1974 to mid-1976 dollars;
- Addition of operating costs that increase the Development Document operating and maintenance costs on the order of 5%;
- Adjustment of technology in place in some process categories for internal consistency and to reasonably approximate the portion of total capital requirements expended through 1974. (ADL assumed that all Phase I subcategories have primary treatment; the Development Documents show no treatment in place for those subcategories).

4. Methodology Used in Calculating Aggregate Costs

Like ADL, H&S used models of representative mills. H&S developed two models for each of its subcategories; the other eight subcategories were represented by one model each. Three cost levels were estimated for each mill model, corresponding to the treatment facilities assumed to be in place (no treatment, primary treatment, or secondary treatment). For a given subcategory, H&S aggregated the mills by size and then by level of in-place treatment. To obtain the aggregate cost for that subcategory, investment and operating costs for each cost level represented by the mill model within a size category were multiplied by the number of mills with the corresponding level of in-place treatment in that size category, assuming certain technology to be employed. Hence, the aggregate costs were based on the number of mills.

Table E-39 summarizes the assumption made by H&S and ADL with regard to the types of external waste water treatment used in each subcategory. The differences were a source of variation in the overall cost estimates, as each treatment process requires a different investment. For example, the investment associated with AS is about 50-80% more than that with ASB.

ADL used the cost models from the Development Documents, which were based on average in-place treatment facilities. In most of the 17 process subcategories used by ADL, cost models were developed for small, medium, and large size categories. To arrive at an aggregate cost for a given subcategory, ADL multiplied the average cost per ton for that category by the corresponding tonnage in that size range. Thus, these total aggregate costs are based on tonnage.

TABLE V-29

SUMMARY OF THE TECHNOLOGY USED BY HAZEN & SAWYER AND ADL TO CALCULATE THE AGGREGATE COSTS FOR BPT

Subcategory	SAB/SABB Hazen & Sawyer	SAB/SABB ADL
Unbleached Kraft	25/75	0/100
NSSC - Sodium	50/50	0/100
- Ammonia	0/100	
Unbleached Kraft/NSSC	25/75	0/100
Recycled Paperboard	25/75	50/50
Construction Paper	Not Included	0/100
BCT Kraft Fine Kraft Dissolving Kraft Market Kraft	50/50	0/100
Sulfite	50/50	0/100
Dissolving Sulfite	50/50	50/50
Soda	33/67	0/100
De-inked	50/50	50/50
Groundwood C-M-N Chemical Mechanical CM	25/75	0,100

	F FI*/F CI*	SAB/SABB
N/I Fine Tissue	50/50	50/50
N/I Fine	50/50	50/50
Coarse Paper	50/50	Not Included

* FI = Flotation

CI = Coagulation/Clarification

APPENDIX F

SUPPORTING MATERIAL FOR NEW MILL COST MODELS

This appendix describes the development of the cost models for selected pulp, paper, and paperboard manufacturing operations and presents the supporting data on which they are based. Table F-1 is an overall summary of the capital and operating costs. Tables F-2 through F-38 summarize the capital and operating costs for each model.

Both the capital and operating costs consist of two discrete parts:

- *Costs related to the direct manufacturing process.* These were derived from earlier work performed by ADL for EPA.[1] Investment and operating cost schedules appearing in the latter report were updated and modified to meet the objectives of this study.

  Note that Tables F-3 through F-38 are only summaries of the original cost schedules. The source document went into considerably greater detail and also included material balances, energy balances, manning tables, and cost sensitivity curves. These should be consulted by those who wish to study the derivation of the capital and operating costs or to determine the effect of changes in selected parameters.

  The costs of complying with OSHA noise regulations are shown separately and included with the direct manufacturing cost. As mentioned in Chapter III, the OSHA costs were estimated by ADL on the basis of information obtained from the American Paper Institute.

- *Costs related to the studied environmental regulations.* Cost estimates for water control were obtained from the Development Documents. Those for air control were obtained from published and unpublished EPA documents. In each case, ADL updated and adjusted the original data to put it on a basis and time period comparable to those used in this study.

1. BASIS OF COST CALCULATIONS

a. Boundary Limits

The operations included in the new mill models extend from the delivery of fiber to the mill to the delivery of rolls of paper or paperboard to the user.

b. Monetary Base

All costs apply to the end of the second quarter of 1975. Because of the uncertainty of future prices, all of the analyses are based on mid-1975 dollars with no escalation for further inflation.

c. Units of Measurement

English units (e.g., short tons) have been used throughout.

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1. Arthur D. Little, Inc., "Analysis of Demand and Supply for Secondary Fiber in the U.S. Paper and Paperboard Industry," prepared for Office of Solid Waste Management Programs, EPA, Contract No. 68-01-2220, March 1975.

Pages 126 and 127 are blank.

[illegible]

[illegible]

Product Sector and Selected Model	Process Category	Mill Capacity, '000 t/y: Pulp	Mill Capacity, '000 t/y: Paper	Capital Investment ($M Cdn)	Operating Cost ($/tonne) Capital	Operating	Total
Unbleached Kraft Paperboard:							
Kraft Linerboard	Unbleached Kraft	1000	1000	340.7	110.7	52.2	170.9
Unbleached Kraft Paper:							
Kraft Bag Paper	Unbleached Kraft	400	230	65.3	174.6	104.1	278.7
NSSC Corrugating Medium:							
Corrugating Medium	NSSC Pulping	450	450	67.7	141.6	52.7	194.3
Recycled Paperboard:							
Recycled Boxboard	Recycled Paperboard	400	400	57.8	181.5	72.9	254.4
Solid Linerboard	" "	730	730	96.1	205.5	62.6	268.0
Wagon Medium	" "	730	730	92.1	142.2	35.7	178.0
Fluting Linerboard	" "	420	420	49.8	157.4	45.6	203.0
Construction Paper:							
None	Construction Paper	--	--	--	--	--	--
Bleached Board & Boxboard:							
Bleached Paperboard (SBS)	BCT Kraft	400	500	144.9	224.0	104.7	328.8
Printing & Writing Paper							
Bond Paper	Fine Kraft	400	300	96.7	272.1	117.0	389.1
Book Paper	Fine Kraft	600	300	94.9	288.9	174.1	463.0
Tissue:							
Tissue Papers	BCT Kraft	400	340	72.6	124.5	240.4	467.0
Tissue Papers	Semi-Int., Fine Hardwood	--	75	20.4	631.8	137.4	742.2
Newsprint:							
Newsprint	Fine Kraft/Groundwood	1,240	550	220.5	188.8	77.9	266.7
Newsprint	De-Inking	--	330	91.8	176.7	60.4	237.1
Bleached Pkg. & Ind. Conv:							
None	--	--	--	--	--	--	--
Unbleached Groundwood Papers							
None	--	--	--	--	--	--	--
Dissolving Pulp:							
Dissolving Pulp	Dissolving Sulfite	700	550	242.4	274.4	102.8	332.3
Bleached Paper Pulp:							
Bleached Market Pulp	Kraft Market pulp	900	800	34.9	198.4	62.7	261.1
Slush Pulp*							
Bleached Kraft 50 Slush Pulp	(Eastern)	800	--	121.0	170.1	--	170.1
" " " "	(Northern)	400	--	121.0	226.4	--	226.4
Bleached Kraft 80 Slush Pulp	(Coastal)	800	--	134.1	121.8	--	121.8
" " " "	(Northern)	400	--	134.0	258.5	--	258.5
Semi-bleached Kraft 50 Slush Pulp		400	--	120.1	205.5	--	205.5
Groundwood Slush Pulp		440	--	73.0	72.3	--	72.3

* Costs to be transferred to the integrated paper/board mill, excludes environmental control costs.

TABLE V-2

FORMAT USED FOR ANNUAL CASH FLOWS FOR THE MANUFACTURE OF SELECTED PRODUCTS

Basis: Product Grade
Production Capacity
Integrated to Pulp Mill
Total Fixed Capital[a], Plant and Buildings

OPERATING YEAR ⟶	–	–	–	1	2 to 7	8	9 to end
CASH FLOW YEAR ⟶	1	2	3	4	5 to 10	11	12 to end
Capacity (000 tpy)	0	0	0	60% of cap.	100% of cap.	⟶	⟶
Fixed Capital,[a] ($Million)	(20% of total)	(40% of total)	(40% of total)	0	0	(as 10% of 1+2)	0
Plant Equipment 16 years	⟵	75%	⟶	0	0	0	0
Buildings 33 years	⟵	25% of fixed capacity	⟶	0	0	0	0
Working Capital ($million)	0	0	@ 1 month del'd cost	@ 2 months del'd cost	0	0	0
Total Delivered Operating Costs ($million/yr), excl. Deprec.							
Direct Mfg. + Cost of Sales (excl. environmental & OSHA)	0	0	0	⟵	b	⟶	⟶
Environmental Control (air and water)	0	0	0	⟵	b	⟶	⟶
OSHA (noise)	0	0	0	⟵	b	⟶	⟶

[a] Includes an allocation of pulp mill total capital requirements

[b] Derived on the basis of 60% of cap'y in 1st operating year and 100% thereafter.

TABLE F-3

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF UNBLEACHED KRAFT LINERBOARD

BASIS: Process: Continuous Kraft Pulping
Production: 1000 tons/day; 345,000 tons/year
Mill Location: Southeast

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Cost	
Direct Manufacturing Process	121
OSHA Regulations	3
Total Fixed Capital	124
Total Working Capital (1 month@ delivered cost)	10
2. Plus Environmental Control Cost	
Water Control - Internal	6.3
External	12.7
Air Control - Economic Level	3.8
Environmental Level	2.9
TOTAL FIXED CAPITAL	148.7
TOTAL WORKING CAPITAL	10

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost	41.9	14,460
Other Raw Materials	4.5	1,550
Hourly Labor	11.4	3,930
Supplies	9.9	3,410
Energy	6.9	2,380
Factory Overhead	4.8	1,660
Capital-related - (less capital recovery)	7.9	2,720
Sub-total, Factory Cost	87.3	30,110
GS&A	7.3	2,520
Freight Out	20.9	7,210
Total Delivered Cost, Direct Mfg.	115.5	39,840
OSHA Regulations	0.3	100
Total Delivered Cost, excluding Federal Environmental Regulations	115.8	39,940
Water Control Regulations (external control only)	5.0	1,740
Air Control Regulations - Economic Recovery	(2.7)	(930)
Environmental Control	0.6	220
Total Delivered Cost (excl. capital recovery)	118.7	40,970

Source: Arthur D. Little, Inc., estimates

TABLE F-4

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF
UNBLEACHED KRAFT BAG PAPER

BASIS: Process: **Integrated to Unbleached kraft-pulping**
Production: **230 tons/day; 75,900 tons/year**
Mill location: **Southeast**

CAPITAL REQUIREMENTS	$MILLion
1. Excluding Environmental Plant	
Direct Manufacturing Program	57
OSHA Regulations	2
Total Fixed Capital	59
Total Working Capital (1 month delivered cost)	1
2. Plus Environmental Control Cost	
Water Control - Internal	1.6
External	3.2
Air Control - Economic level	0.7
Environmental level	0.8
TOTAL FIXED CAPITAL	65.3
TOTAL WORKING CAPITAL	1

OPERATING COSTS	$/ton	$000/Year
Fiber Cost	**65.5**	**4,960**
Other Raw Materials	**13.5**	**1,030**
Hourly Labor	**13.5**	**1,030**
Supplies	7.8	590
Energy	10.3	780
Factory Overhead	4.8	360
Capital-related (less capital-recovery)	9.2	700
Sub-total, Factory Cost	124.5	9,950
OS&A	7.3	550
Freight Out	18.8	1,430
Total Delivered Cost, Direct Mfg.	150.6	11,430
OSHA Regulations	0.4	30
Total Delivered Cost (excl. capital recovery)	151.0	11,460
Water Control Regulations (external control only)	5.7	430
Air Control Regulations - Economic Recovery	(2.8)	(210)
Environmental Control	0.7	50
Total Delivered Cost	154.6	11,730

Source: Arthur D. Little, Inc.; estimates

TABLE F-5

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF NSSC CORRUGATING MEDIUM

BASIS: Process: NSSC Pulping, Sodium Base
Production: 450 tons/day; 155,300 tons/year
Mill Location: Southwest

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Cost	
Direct Manufacturing Process	50
OSHA Regulations	1
Total Fixed Capital	51
Total Working Capital (1 month delivered cost)	5
2. Plus Environmental Control Cost	
Water Control - Internal	1
External	10.6
Air Control - Economic Level	-
Environmental Level	1.1
TOTAL FIXED CAPITAL	67.7
TOTAL WORKING CAPITAL	6

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost	33.3	5,170
Other Raw Materials	19.2	2,980
Hourly Labor	17.5	2,720
Supplies	7.3	1,130
Energy	16.7	2,600
Factory Overhead	8.2	1,270
Capital-related (less capital recovery)	7.3	1,130
Sub-total, Factory Cost	109.5	17,000
G&A	7.3	1,130
Freight Out	14.6	2,270
Total Delivered Cost, Direct Mfg.	131.4	20,400
OSHA Regulations	0.6	100
Total Delivered Cost, excluding Federal Environmental Regulations	132.0	20,506
Water Control Regulations (External control only)	10.7	1,660
Air Control Regulations - Economic Recovery	-	-
Environmental Control	0.7	110
Total Delivered Cost, (excl. capital recovery)	143.4	22,270

Source: Arthur D Little, Inc., estimates

TABLE F-6

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF
RECYCLED BOXBOARD, 18 PT. CLAY COATED

BASIS: Process: Secondary Fiber Pulping
Production: 400 tons/day; 132,000 tons/year
Mill Location: North Central

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Cost	
Direct Manufacturing Process	49.7
OSHA Regulations	1
Total Fixed Capital	50.7
Total Working Capital (3 months' delivered cost)	6
2. Plus Environmental Control Cost	
Water Control - Internal	1.7
External	5.1
Air Control - Economic Level	-
Environmental Level	0.3
TOTAL FIXED CAPITAL	57.8
TOTAL WORKING CAPITAL	6

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost	65.5	8,650
Other Raw Materials	14.2	1,880
Hourly Labor	16.1	2,120
Supplies	11.5	1,520
Energy	23.1	3,050
Factory Overhead	13.1	1,730
Capital-related (less capital recovery)	8.7	1,150
Sub-total, Factory Cost	152.3	20,100
OS&A	12.4	1,640
Freight Out	15.7	2,070
Total Delivered Cost, Direct Mfg.	180.4	23,810
OSHA Regulations	0.5	70
Total Delivered Cost, excluding Federal Environmental Regulations	180.9	23,880
Water Control Regulations (external control only)	4.1	540
Air Control Regulations - Economic Recovery	-	-
Environmental Control	0.5	70
Total Delivered Cost (excl. capital recovery)	185.5	24,490

*Operating costs for water control (less depreciation and interest) are essentially all for external control. Operation and maintenance for internal control nets

Source: Arthur D. Little, Inc., estimates

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TABLE P-7

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF JUTE LINERBOARD

BASIS: Process: Secondary Fiber Pulping
Production: 330 tons/day; 109,000 tons/year
Mill Location: North Central

CAPITAL REQUIREMENTS	$/Million
I. Excluding Environmental Cost	
Direct Manufacturing Process	31.7
OSHA Regulations	1
Total Fixed Capital	32.7
Total Working Capital (1 month@ delivered cost)	6
II. Plus Environmental Control Cost	
Water Control - Internal	1.5
External	4.6
Air Control - Economic Level	-
Environmental Level	0.3
TOTAL FIXED CAPITAL	39.1
TOTAL WORKING CAPITAL	6

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost	60.4	5,580
Other Raw Materials	19.5	1,800
Hourly Labor	9.6	1,050
Supplies	4.6	490
Energy	24.8	2,700
Factory Overhead	6.5	710
Capital-related (less capital recovery)	6.5	710
Sub-total, Factory Cost	128.5	14,040
G&A	7.3	800
Freight Out	13.8	1,500
Total Delivered Cost, Direct Mfg.	150.0	16,340
OSHA Regulations	0.6	70
Total Delivered Cost, excluding Federal Environmental Regulations	150.6	16,410
Water Control Regulations (external control only)	4.4	480
Air Control Regulations - Economic Recovery	-	-
Environmental Control	0.5	60
Total Delivered Cost, (excluding capital recovery)	155.5	16,950

Source: Arthur D. Little, Inc., estimates.

TABLE F-8

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF BOGUS MEDIUM

BASIS: Process: Secondary Fiber Pulping
Production: 330 tons/day; 109,000 tons/year
Mill Location: North Central

CAPITAL REQUIREMENTS	$MILLION
1. Excluding Environmental Cost	
Direct Manufacturing Process	24.8
OSHA Regulations	1
Total Fixed Capital	25.8
Total Working Capital (3 months' delivered cost)	4
2. Plus Environmental Control Cost	
Water Control - Internal	1.5
External	4.6
Air Control - Economic Level	-
Environmental Level	0.2
TOTAL FIXED CAPITAL	32.1
TOTAL WORKING CAPITAL	4

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost	62.0	6,760
Other Raw Materials	3.6	390
Hourly Labor	8.6	940
Supplies	4.1	440
Energy	28.2	3,070
Factory Overhead	6.3	690
Capital-related (less capital recovery)	5.2	570
Sub-total, Factory Cost	118.0	12,860
OS&A	7.3	800
Freight Out	12.5	1,360
Total Delivered Cost, Direct Mfg.	137.9	15,020
OSHA Regulations	0.6	70
Total Delivered Cost, excluding Federal Environmental Regulations	138.5	15,090
Water Control Regulations (external control only)	4.4	480
Air Control Regulations - Economic Recovery	-	-
Environmental Control	0.4	50
Total Delivered Cost, (excl. capital recovery)	143.2	15,260

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Source: Arthur D. Little, Inc., estimates.

TABLE V-9

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF
GYPSUM LINERBOARD

BASIS: Process: Secondary Fiber Pulping
Production: 400 tons/day; 132,000 tons/year
Mill location: North Central

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Plant	
Direct Manufacturing Process	41.7
OSHA Regulations	1
Total Fixed Capital	42.7
Total Working Capital (1 month[illegible] delivered cost)	5
2. Plus Environmental Control Cost	
Water Control - Internal	1.7
External	5.1
Air Control - Economic Level	-
Environmental Level	0.3
TOTAL FIXED CAPITAL	49.8
TOTAL WORKING CAPITAL	5

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost	60.1	7,930
Other Raw Materials	5.0	660
Hourly Labor	14.7	1,940
Supplies	10.1	1,370
Energy	21.0	2,770
Factory Overhead	12.0	1,590
Capital-related (less capital recovery)	7.2	950
Sub-total, Factory Cost	130.1	17,210
G&A	10.0	1,320
Freight Out	12.0	1,580
Total Delivered Cost, Direct Mfg.	152.1	20,110
OSHA Regulations	0.5	70
Total Delivered Cost, excluding Federal Environmental Regulations	152.8	20,180
Water Control Regulations (external control only)		
Air Control Regulations - Economic Recovery	4.1	540
Environmental Control	0.5	60
Total Delivered Cost, (excl. capital recovery)	157.4	20,780

Source: Arthur D. Little, Inc., estimates.

TABLE F-10

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF SBB BOARD

BASIS: Process: Integrated to Bleached Kraft Pulp
Production: 500 tons/day; 165,000 tons/year
Mill Location: Southeast

CAPITAL REQUIREMENTS	$MILLION
I. Excluding Environmental Cost	
Direct Manufacturing Process	121
OSHA Regulations	4
Total Fixed Capital	125
Total Working Capital (3 months delivered cost)	9
II. Plus Environmental Control Cost	
Water Control - Internal	4.1
External	12.0
Air Control - Economic Level	1.6
Environmental Level	2.1
TOTAL FIXED CAPITAL	144.8
TOTAL WORKING CAPITAL	9

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost (Slush pulp: 0.42 ton HW; 0.63 ton SW)	116.4	19,190
Other Raw Materials	16.5	2,720
Hourly Labor	9.3	1,540
Supplies	7.9	1,300
Energy	8.9	1,470
Factory Overhead	3.9	640
Capital-related (less capital recovery)	5.9	970
Sub-total, Factory Cost	168.7	27,830
G&A	13.6	2,240
Freight Out	31.4	5,180
Total Delivered Cost, Direct Mfg.	213.7	35,250
OSHA Regulations	0.4	70
Total Delivered Cost, excluding Federal Environmental Regulations	214.1	35,320
Water Control Regulations (external control only)	7.9	1,300
Air Control Regulations - Economic Recovery	(3.0)	(490)
Environmental Control	0.8	130
Total Delivered Cost, (excl. capital recovery)	219.8	36,260

Source: Arthur D. Little, Inc.; estimates.

TABLE F-11

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF BOND PAPER (ROLLS)

BASIS: Process: Integrated to Bleached Kraft Pulp
Production: 300 tons/day; 100,000 tons/year
Mill Location: Northeast

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Cost	
Direct Manufacturing Process	84
OSHA Regulations	2
Total Fixed Capital	86
Total Working Capital (1 month@ delivered cost)	7
2. Plus Environmental Control Cost	
Water Control - Internal	2.1
External	6.4
Air Control - Economic Level	1.0
Environmental Level	1.2
TOTAL FIXED CAPITAL	96.7
TOTAL WORKING CAPITAL	7

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost (Slush Pulp: 0.473 ton HW; 0.473 ton SW)	126.3	12,630
Other Raw Materials	18.3	1,830
Hourly Labor	11.5	1,150
Supplies	15.1	1,510
Energy	15.0	1,500
Factory Overhead	5.4	540
Capital-related (less capital recovery)	9.2	920
Sub-total, Factory Cost	200.8	20,080
G&A	35.0	3,500
Freight Out	31.0	3,100
Total Delivered Cost, Direct Mfg.	266.8	26,680
OSHA Regulations	0.4	40
Total Delivered Cost, excluding Federal Environmental Regulations	267.2	26,720
Water Control Regulations (external control only)	7.0	700
Air Control Regulations - Economic Recovery	(3.0)	(300)
Environmental Control	0.9	90
Total Delivered Cost, (excluding capital recovery)	272.1	27,210

Source: Arthur D. Little, Inc.; estimates.

TABLE F-12

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF
BOOK PAPER (ROLLS)

BASIS: Process: Integrated to Bleached Kraft Pulp
Production: 300 ton/day; 100,000 ton/year
Mill Location: Northeast

CAPITAL REQUIREMENTS	$MILLion
1. Excluding Environmental Cost	
Direct Manufacturing Process	82
OSHA Regulations	2
Total Fixed Capital	84
Total Working Capital (3 months delivered cost)	7
2. Plus Environmental Control Cost	
Water Control - Internal	2.1
External	6.4
Air Control - Economic Level	1.0
Environmental Level	1.3
TOTAL FIXED CAPITAL	94.8
TOTAL WORKING CAPITAL	7

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost (Slush Pulp; 0.70 tons BW; 0.17 tons HW)	107.1	10,710
Other Raw Materials	47.0	4,700
Hourly Labor	11.7	1,170
Supplies	16.6	1,660
Energy	19.0	1,900
Factory Overhead		
Capital-related (less capital recovery)	6.3	630
	9.9	990
Sub-total, Factory Cost	217.6	21,760
G&A	35.0	3,500
Freight Out	31.0	3,100
Total Delivered Cost, Direct Mfg.	283.6	28,360
OSHA Regulations	0.4	40
Total Delivered Cost, excluding Federal Environmental Regulations	284.0	28,400
Water Control Regulations (external control only)	7.0	700
Air Control Regulations - Economic Recovery	(3.0)	(300)
Environmental Control	0.9	90
Total Delivered Cost, (excl. capital recovery)	288.9	28,890

Source: Arthur D. Little, Inc.; estimates.

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TABLE V-13

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF
TISSUE PAPER, JUMBO ROLLS

BASIS: Process: **Integrated to Bleached Kraft Pulp**
Production: **150 tons/day; 49,500 ton/yr**
Mill Location: **Northeast**

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Cost	
Direct Manufacturing Process	48
OSHA Regulations	
Total Fixed Capital	
Total Working Capital (3 months delivered cost)	
2. Plus Environmental Control Cost	*
Water Control - Internal	
External	
Air Control - Economic Level	
Environmental Level	
TOTAL FIXED CAPITAL	
TOTAL WORKING CAPITAL	

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost (Slush Pulp: 0.52 ton HW; 0.33 ton SW)	138.8	6,870
Other Raw Materials	9.9	490
Hourly Labor	15.2	750
Supplies	9.6	480
Energy	5.3	260
Factory Overhead	6.9	340
Capital-related (less capital recovery)	11.5	570
Sub-total, Factory Cost	197.2	9,760
OS&A		
Freight Out		
Total Delivered Cost, Direct Mfg.	*	*
OSHA Regulations		
Total Delivered Cost, excluding Federal Environmental Regulations		
Water Control Regulations (external control only)		
Air Control Regulations - Economic Recovery		
Environmental Control		
Total Delivered Cost, (excluding capital recovery)		

*Interim product costs for environmental control are shown with the final product.

Source: Arthur D. Little, Inc., estimates

TABLE F-14

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF TISSUE PAPERS, CONVERTED (30% TOILET, 40% TOWEL, 10% NAPKIN)

BASIS: Process: 2 Line Converting
Production: 163 tons/day; 53,800 tons/year, packaged
Mill Location: Northeast

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Cost	
Direct Manufacturing Process	63
OSHA Regulations	2
Total Fixed Capital	65
Total Working Capital (3 months delivered cost)	7
2. Plus Environmental Control Cost	
Water Control - Internal	1.2
External	1.6
Air Control - Economic Level	0.5
Environmental Level	0.6
TOTAL FIXED CAPITAL	70.9
TOTAL WORKING CAPITAL	7

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost (Jumbo rolls, 0.933 ton net)	184.0	9,900
Other Raw Materials	-	-
Hourly Labor	34.4	1,850
Supplies	43.7	2,350
Energy	6.1	330
Factory Overhead	19.5	1,050
Capital-related (less capital recovery)	6.1	330
Sub-total, Factory Cost	293.8	15,810
G&A	160.0	8,610
Freight Out	69.0	3,710
Total Delivered Cost, Direct Mfg.	522.8	28,130
OSHA Regulations	0.4	20
Total Delivered Cost, excluding Federal Environmental Regulations	523.2	28,150
Water Control Regulations (external control only)	7.2	390
Air Control Regulations - Economic Recovery	(3.0)	(160)
Environmental Control	1.2	60
Total Delivered Cost, (excl. capital recovery)	528.5	28,440

Source: Arthur D. Little, Inc.; estimates.

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TABLE F-15

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF
DEINKED TISSUE PAPER (JUMBO ROLLS)

BASIS: Process: Secondary Fiber, Deinking
Production: 70 ton/day; 23,000 ton/year
Mill Location: Northeast

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Cost	
Direct Manufacturing Process OSHA Regulations	17
Total Fixed Capital	
Total Working Capital (3 months delivered cost)	
2. Plus Environmental Control Cost	*
Water Control - Internal	
External	
Air Control - Economic Level	
Environmental Level	
TOTAL FIXED CAPITAL	
TOTAL WORKING CAPITAL	

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost	190.4	4,380
Other Raw Materials	18.7	430
Hourly Labor	41.3	950
Supplies	22.6	520
Energy	29.1	670
Factory Overhead	26.5	610
Capital-related (less capital recovery)	16.5	380
Sub-total, Factory Cost	345.1	7,940
G&A		
Freight Out	*	*
Total Delivered Cost, Direct Mfg.		
OSHA Regulations		
Total Delivered Cost, excluding Federal Environmental Regulations		
Water Control Regulations (external control only)		
Air Control Regulations - Economic Recovery		
Environmental Control		
Total Delivered Cost, (excl. capital recovery)		

*Interim product costs for environmental control are shown with the final product.

Source: Arthur D. Little, Inc.; estimates.

TABLE F-16

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF DEINKED TISSUE, CONVERTED (50% TOILET, 40% TOWEL, 10% NAPKIN)

BASIS: Process: 1 Line Converting
Production: 76 ton/day; 25,000 tons/year
Mill Location: Northeast

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Cost	
Direct Manufacturing Process	23.9
OSHA Regulations	1
Total Fixed Capital	24.9
Total Working Capital (1 month@ delivered cost)	4
2. Plus Environmental Control Cost	
Water Control - Internal	0.4
External	3.0
Air Control - Economic Level	-
Environmental Level (SIPs)	0.1
TOTAL FIXED CAPITAL	28.4
TOTAL WORKING CAPITAL	4

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost (Jumbo rolls, 0.933 ton net)	322.0	8,050
Other Raw Materials	-	-
Hourly Labor	34.4	860
Supplies	43.2	1,080
Energy	6.0	150
Factory Overhead		
Capital-related (less capital recovery)	19.6	490
	6.8	170
Sub-total, Factory Cost	432.0	10,800
G&A	103.0	2,580
Freight Out	61.0	1,520
Total Delivered Cost, Direct Mfg.	596.0	14,900
OSHA Regulations	2.8	70
Total Delivered Cost, excluding Federal Environmental Regulations	598.8	14,970
Water Control Regulations (external control only)	11.6	290
Air Control Regulations - Economic Recovery	-	-
Environmental Control (SIPs)	0.4	10
Total Delivered Cost, (excl. capital recovery)	610.8	15,270

Source: Arthur D. Little, Inc.; estimates.

TABLE F-17

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF NEWSPRINT

BASIS: Process: Integrated to Semi-Bleached Kraft and Groundwood
Production: 550 ton/day; 187,000 ton/year
Mill location: Northeast

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Cost	
Direct Manufacturing Process	108
OSHA Regulations	2
Total Fixed Capital	110
Total Working Capital (3 months delivered cost)	8
2. Plus Environmental Control Cost	
Water Control - Internal	2.1
External	7.1
Air Control - Economic Level	0.5
Environmental Level	0.8
TOTAL FIXED CAPITAL	120.5
TOTAL WORKING CAPITAL	8

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost (Slush pulp: 0.778 ton GW; 0.257 ton kraft)	88.5	16,550
Other Raw Materials	2.2	410
Hourly Labor	7.0	1,300
Supplies	8.7	1,630
Energy	13.4	2,510
Factory Overhead	2.9	540
Capital-related (less capital recovery)	7.8	1,460
Sub-total, Factory Cost	130.5	24,400
OS&A	13.1	2,450
Freight Out	20.9	3,910
Total Delivered Cost, Direct Mfg.	164.5	30,760
OSHA Regulations	0.5	100
Total Delivered Cost, excluding Federal Environmental Regulations	165.0	30,860
Water Control Regulations (external control only)	4.2	780
Air Control Regulations - Economic Recovery	(0.8)	(150)
Environmental Control	0.4	80
Total Delivered Cost, (excl. capital recovery)	168.8	31,570

Source: Arthur D. Little, Inc.; estimates.

TABLE F-18

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF RECYCLED NEWSPRINT

BASIS: Process: Secondary Fiber Pulping
Production: 330 tons/day; 112,000 tons/year
Mill Location: Northeast

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Cost	
Direct Manufacturing Process	41.8
OSHA Regulations	1
Total Fixed Capital	42.8
Total Working Capital (3 months' delivered cost)	5
2. Plus Environmental Control Cost	1.6
Water Control - Internal	-
External	11.3
Air Control - Economic Level	-
Environmental Level (SIPs)	0.2
TOTAL FIXED CAPITAL	55.3
TOTAL WORKING CAPITAL	5

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost	53.7	6,010
Other Raw Materials	12.0	1,350
Hourly Labor	12.0	1,340
Supplies	11.6	1,300
Energy	33.0	3,700
Factory Overhead	8.0	900
Capital-related (less capital related)	8.5	950
Sub-total, Factory Cost	138.8	15,550
G&A	13.0	1,460
Freight Out	12.5	1,400
Total Delivered Cost, Direct Mfg.	164.3	18,410
OSHA Regulations	0.6	70
Total Delivered Cost, excluding Federal Environmental Regulations	165.0	18,480
Water Control Regulations (external control only)	11.3	1,270
Air Control Regulations - Economic Recovery	-	-
Environmental Control	0.4	40
Total Delivered Cost, (excl. capital recovery)	176.7	19,790

Source: Arthur D. Little, Inc., estimates

TABLE F-19

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF
SULFITE DISSOLVING PULP

BASIS: Process: **Bleached Magnesium Base Sulfite; Cont. Pulping with Chemical Recovery**
Production: **550 ADT tons/day; 190,000 tons/year**
Mill Location: **Northwest**

CAPITAL REQUIREMENTS	$MILLion
1. Excluding Environmental Cost	
Direct Manufacturing Process	130
OSHA Regulations	3
Total Fixed Capital	133
Total Working Capital (3 months delivered cost)	10
2. Plus Environmental Control Cost	
Water Control - Internal	3.5
External	24.0
Air Control - Economic Level	-
Environmental Level	1.1
TOTAL FIXED CAPITAL	161.6
TOTAL WORKING CAPITAL	11

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost	79.8	15,160
Other Raw Materials	23.0	4,370
Hourly Labor	23.1	4,390
Supplies	13.5	2,570
Energy	4.2	790
Factory Overhead	8.3	1,580
Capital-related (less capital recovery)	15.5	2,950
Sub-total, Factory Cost	167.4	31,810
G&A	13.6	2,580
Freight Out	31.4	5,970
Total Delivered Cost, Direct Mfg.	212.4	40,360
OSHA Regulations	0.5	100
Total Delivered Cost, excluding Federal Environmental Regulations	212.9	40,460
Water Control Regulations (external control only)	16.1	3,060
Air Control Regulations - Economic Recovery	-	-
Environmental Control	0.6	110
Total Delivered Cost, (excl. capital recovery)	229.6	43,630

Source: Arthur D. Little, Inc.; estimates.

TABLE F-20

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF
BLEACHED KRAFT SOFTWOOD MARKET PULP

BASIS: Process: Continuous Kraft Pulping, CEDED Bleaching
Production: 800 ADT/day; 276,000 ADT/year
Mill Location: Southeast

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Cost	
Direct Manufacturing Process	155
OSHA Regulations	3
Total Fixed Capital	158
Total Working Capital (3 months delivered cost)	12
2. Plus Environmental Control Cost	
Water Control - Internal	5.2
External	15.1
Air Control - Economic Level	2.6
Environmental Level	3.1
TOTAL FIXED CAPITAL	184.0
TOTAL WORKING CAPITAL	12

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost	51.6	14,240
Other Raw Materials	25.8	7,120
Hourly Labor	15.8	4,360
Supplies	11.9	3,290
Energy	8.0	2,200
Factory Overhead	4.7	1,300
Capital-related (less capital recovery)	12.7	3,510
Sub-total, Factory Cost	130.5	36,020
G&A	13.6	3,760
Freight Out	31.8	8,660
Total Delivered Cost, Direct Mfg.	175.5	48,440
OSHA Regulations	0.4	100
Total Delivered Cost, excluding Federal Environmental Regulations	175.9	48,540
Water Control Regulations (external control only)	6.9	1,900
Air Control Regulations - Economic Recovery	(3.0)	(830)
Environmental Control	0.8	230
Total Delivered Cost, (excl. capital recovery)	180.6	49,840

Source: Arthur D. Little, Inc.; estimates.

TABLE V-21

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF
SOUTHERN BLEACHED KRAFT SOFTWOOD SLUSH PULP

BASIS: Process: Continuous Kraft Pulping; CEDED Bleaching
Production: 800 ADT/day; 276,000 ADT/Year
Mill Location: Southeast

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Cost	
Direct Manufacturing Process	
OSHA Regulations	125
Total Fixed Capital	
Total Working Capital (1 month@ delivered cost)	
2. Plus Environmental Control Cost	*
Water Control - Internal	
External	
Air Control - Economic Level	
Environmental Level	
TOTAL FIXED CAPITAL	
TOTAL WORKING CAPITAL	

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost	51.6	14,240
Other Raw Materials	28.0	7,730
Hourly Labor	11.9	3,290
Supplies	6.5	1,790
Energy	2.9	800
Factory Overhead	3.6	990
Capital-related (less capital recovery)	11.3	3,120
Sub-total, Factory Cost	115.8	31,960
OS&A	*	*
Freight Out	*	*
Total Delivered Cost, Direct Mfg.		
OSHA Regulations	*	*
Total Delivered Cost, excluding Federal Environmental Regulations		
Water Control Regulations (external control only)		
Air Control Regulations - Economic Recovery		
Environmental Control		
Total Delivered Cost, (excl. capital recovery)		

*Interim product costs for environmental control are shown with the final product.

Source: Arthur D. Little, Inc.; estimates.

TABLE P-22

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF NORTHERN BLEACHED KRAFT, SOFTWOOD SLUSH PULP

BASIS: Process: Continuous Kraft Pulping, CEDED Bleaching
Production: 800 ADT/day; 276,000 ADT/year
Mill Location: Northeast

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Cost	
Direct Manufacturing Process	125
OSHA Regulations	
Total Fixed Capital	
Total Working Capital (3 months delivered cost)	
2. Plus Environmental Control Cost	*
Water Control - Internal	
External	
Air Control - Economic Level	
Environmental Level	
TOTAL FIXED CAPITAL	
TOTAL WORKING CAPITAL	

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost	83.0	22,910
Other Raw Materials	28.5	7,860
Hourly Labor	10.4	2,870
Supplies	6.5	1,790
Energy	7.2	1,990
Factory Overhead	3.6	990
Capital-related (less capital recovery)	11.3	3,120
Sub-total, Factory Cost	150.5	41,530
G&A		
Freight Out		
Total Delivered Cost, Direct Mfg.	*	*
OSHA Regulations		
Total Delivered Cost, excluding Federal Environmental Regulations		
Water Control Regulations (external control only)		
Air Control Regulations - Economic Recovery		
Environmental Control		
Total Delivered Cost, (excl. capital recovery		

*Interim product costs for environmental control are shown with the final product.

Source: Arthur D. Little, Inc., estimates.

TABLE F-23

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF SOUTHERN BLEACHED KRAFT HARDWOOD SLUSH PULP

BASIS: Process: Continuous Kraft Pulping, CEDED Bleaching
Production: 800 ADT/day; 276,000 ADT/year
Mill Location: Southeast

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Cost	
Direct Manufacturing Process	
OSHA Regulations	116
Total Fixed Capital	
Total Working Capital (3 months' delivered cost)	
2. Plus Environmental Control Cost	*
Water Control - Internal	
External	
Air Control - Economic Level	
Environmental Level	
TOTAL FIXED CAPITAL	
TOTAL WORKING CAPITAL	

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost	42.2	11,650
Other Raw Materials	26.3	7,260
Hourly Labor	10.5	2,890
Supplies	6.2	1,710
Energy	3.7	1,030
Factory Overhead	3.5	970
Capital-related (less capital recovery)	10.7	2,950
Sub-total, Factory Cost	103.1	28,460
G&A		
Freight @	*	*
Total Delivered Cost, Direct Mfg.		
OSHA Regulations		
Total Delivered Cost, excluding Federal Environmental Regulations		
Water Control Regulations (external control only)		
Air Control Regulations - Economic Recovery		
Environmental Control		
Total Delivered Cost, (excl. capital recovery)		

*Interim product costs for environmental control are shown with the final product.

Source: Arthur D. Little, Inc.; estimates.

TABLE P-24

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF
NORTHERN BLEACHED KRAFT HARDWOOD SLUSH PULP

BASIS: Process: Continuous Kraft Pulping; CEDED Bleaching
Production: 800 ADT/day; 276,000 ADT/year
Mill Location: Northeast

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Cost	
Direct Manufacturing Process	
OSHA Regulations	116
Total Fixed Capital	
Total Working Capital (3 months' delivered cost)	
2. Plus Environmental Control Cost	*
Water Control - Internal	
External	
Air Control - Economic Level	
Environmental Level	
TOTAL FIXED CAPITAL	
TOTAL WORKING CAPITAL	

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost	52.6	14,520
Other Raw Materials	26.3	7,260
Hourly Labor	9.8	2,700
Supplies	6.2	1,720
Energy	7.8	2,150
Factory Overhead	3.0	830
Capital-related (less capital recovery)	10.7	2,950
Sub-total, Factory Cost	116.4	32,130
OH&A	*	*
Freight Out		
Total Delivered Cost, Direct Mfg.		
OSHA Regulations		
Total Delivered Cost, excluding Federal Environmental Regulations		
Water Control Regulations (external control only)		
Air Control Regulations - Economic Recovery		
Environmental Control		
Total Delivered Cost, (excl. capital recovery)		

*Interim product costs for environmental control are shown with the final product.

Source: Arthur D. Little, Inc.; estimates.

TABLE F-25

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF SEMI-BLEACHED KRAFT SOFTWOOD SLUSH PULP

BASIS: Process: Continuous Kraft Pulping; CED Bleaching
Production: 800 tons/day; 276,000 tons/year**
Mill Location: Northeast

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Regulations:	
Direct Manufacturing Process	120
OSHA Regulations	
Total Fixed Capital	
Total Working Capital (3 months delivered Cost)	
2. Plus Effluent Control Cost	*
Water Control - Internal	
- External	
Air Control - Economic Level	
- Environmental Level	
Total Fixed Capital	
Toal Working Capital	

OPERATING COST ITEM	$/Ton	$000/Year
Fiber Cost	75.8	20,920
Other Raw Materials	15.2	4,200
Hourly Labor	10.4	2,870
Supplies	6.5	1,790
Energy	1.2	080
Factory Overhead	3.6	990
Capital Related (less capital recovery)	10.8	2,980
Sub-total, Factory Cost	125.5	14,630
OH&A		
Freight Out	*	*
Total Delivered Cost, Direct Mfg.		
OSHA Regulations		
Total Delivered Cost, excl. Federal Environmental Regulations		
Water Control Regulations		
Air Control Regulations - Economic Recovery		
Total Del'd cost, (excl. capital recovery)		

* Interim product costs for environmental control are shown with the final product.

** Semi-bleached kraft to newsprint only; remainder of production fully bleached.

Source: Arthur D. Little, Inc.; estimates.

TABLE F-26

SUMMARY OF CAPITAL AND OPERATING COSTS FOR THE MANUFACTURE OF GROUNDWOOD SLUSH PULP

BASIS: Process: Stone Groundwood
Production: 440 ADT/day; 150,000 ADT/year
Mill Location: Northeast

CAPITAL REQUIREMENTS	$Million
1. Excluding Environmental Cost	
Direct Manufacturing Process	23
OSHA Regulations	
Total Fixed Capital	
Total Working Capital (1 month@ delivered cost)	
2. Plus Environmental Control Cost	*
Water Control - Internal	
External	
Air Control - Economic Level	
Environmental Level	
TOTAL FIXED CAPITAL	
TOTAL WORKING CAPITAL	

OPERATING COSTS	$/Ton	$000/Year
Fiber Cost	35.9	5,390
Other Raw Materials	1.9	280
Hourly Labor	11.3	1,700
Supplies	2.1	310
Energy	11.6	1,740
Factory Overhead	5.7	850
Capital-related (less capital recovery)	3.8	570
Sub-total, Factory Cost	72.3	10,840
G&A		
Freight Out	*	*
Total Delivered Cost, Direct Mfg.		
OSHA Regulations		
Total Delivered Cost, excluding Federal Environmental Regulations		
Water Control Regulations (external control only)		
Air Control Regulations - Economic Recovery		
Environmental Control		
Total Delivered Cost, (excl. capital recovery)		

*Interim product costs for environmental control are shown with the final product.

Source: Arthur D. Little, Inc., estimates

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d. Selection of Products

The specific paper and paperboard products considered in the models were selected from the principal product sectors. The selection was based upon the relative importance of the product in its sector from a tonnage standpoint.

e. Mill Characteristics

All cost models relate to new mill installations that typify good technical practice in 1975. No model represents the cost of an actual mill.

A typical scale of operation was assumed in all the models. A relatively large capacity was used for virgin fiber pulping, one considered economical by 1975 standards but not the largest possible. For papermaking operations integrated to virgin pulping, ADL selected the largest practical size for a single machine, which is typical of current installations. For nonintegrated secondary fiber operations, a single machine capacity smaller than the largest practical was selected; this is representative of the existing industry, since economic availability of secondary fiber rather than machine size is the limiting factor in plant capacity.

Mill capacity was defined on a daily tonnage basis, and annual capacity was obtained by multiplying this tonnage by net operating days per year. The latter are total days of actual mill operation after subtracting scheduled down-time for holidays and estimated maintenance shutdowns. Seven paid holidays were allowed, and it was assumed that the mill would operate on three of them. Another seven days were allowed for scheduled maintenance shutdowns. Of the remaining 354 on-stream days, it was estimated that commodity grades (newsprint, board products, corrugating medium, and market pulp) would have a total productive operation of 340 to 345 days. For noncommodity grades, ADL estimated 330 productive days to reflect more frequent cleanup and grade changes.

Plant locations are consistent with existing paper industry patterns. For products where a number of geographic areas could be considered typical, the models are concentrated in one area to emphasize fiber furnish and product grade as the primary variables in cost and profitability estimates.

A large portion of the kraft pulp sector is located in the Southeast, where costs differ considerably from those in other areas. The typical models for bleached kraft paper grades are located in the Northeast, but bleached softwood and hardwood kraft pulp models have also been prepared for the Southeast to indicate the influence of plant location on the cost of these products.

f. Nature and Precision of Specified Conditions

To prepare cost estimates, ADL postulated the operating and marketing conditions for each model. Some conditions are affected by plant location, such as the cost of fuel and power, the cost of virgin and secondary fiber, and the availability of virgin fiber as roundwood or chips and can be clearly defined. Other conditions are affected by plant size; for example, whether it is more economical to generate or to purchase power. These conditions also are amenable to analytical analysis. Some conditions can vary considerably from one mill to another for the same product and capacity, and thus are more difficult to define. Such conditions include: manning requirements, maintenance, utility consumption, chemical usage, fiber yield, and factory overhead. Selling price, sales expense, general administration costs, and freight (as affected by the distribution of customers) are all influenced by individual company characteristics.

The models are based on the use of a single paper machine; however, the same amount of a product could be made on two or more smaller machines at significantly different cost. Thus, while every effort has been made to select typical conditions, different but equally valid assumptions can be made.

In addition to variations from the conditions specified, there is an inherent lack of precision in estimating present costs, or updating historical costs, when economic conditions are fluctuating rapidly.

One of the key variables is scale of operation (plant capacity). All capacities in the models are based on the use of a single machine.

The variability of each major production and cost item, and the treatment of these items, is as follows:

(1) *Product Mix.* A single typical product grade or simplified product mix is used in each model. Most mills in the studied categories and size ranges (with the exception of sulfite dissolving pulp) make a variety of product grades with different selling prices. The selection of an "average value" single product or simplified grade structure is hypothetical but adequate for estimating an example of a category.

(2) *Fiber Furnish and Other Raw Materials.* The exact fiber furnish and other raw materials requirements are determined by product specifications. Thus, cost estimates for these items are simplified to the same extent that product mix is simplified. In addition, fiber furnish and cost for a particular product can vary because of mill specifics, such as geographic variation in cost and availability of wood species, corporate integration to timberlands, intra-company pulp transfer, and accessibility of waste paper. The cost estimates are reasonable examples based on selected products and specified mill conditions. In interpreting and using these examples, however, one must consider possible variations in product lines, mill conditions, and actual costs under specified conditions.

(3) *Sales and Freight Costs.* ADL has estimated sales and freight costs as a function of the specific product quantity produced and sold on the open market. Consideration should be given to variability that results from actual product mix, corporate integration forward to intermediate consumers or converters, and the location of markets.

(4) *Operating and Packaging Supplies.* Costs for operating and packaging supplies are estimated for specific processes and products. They do not vary significantly except for consumer products (e.g., tissue papers), for which packaging materials are a major and quite variable cost component for different products, or for the same product packaged in different ways.

(5) *Direct Labor and Factory Overhead.* ADL estimated direct labor and factory overhead costs on the basis of a normal manpower complement for the specified product and process. Manpower requirements are a function of production per paper machine as well as total mill output. Wages and labor efficiency can vary because of geographic location or individual mill differences. In addition to these

inherent variations, many overhead costs and some labor positions are discretionary. However, only the inherent variability of wages, salaries, and efficiency need be considered. Major reductions in discretionary costs could be made only through specialized production arrangements or markets, or at the sacrifice of product quality control and overall technical competence. None of these conditions is consistent with the long-range viability of a mill selling on the open market.

(6) *Energy Consumption.* Steam and power usage has been estimated on the basis of normal requirements for the process and selected product at the rates prevailing for the specified location. Geographic variations in rates for fuel and power is significant, and mill-to-mill variations in consumption are considerable. On-site power generation, an option for mills with high steam consumption, radically affects purchased power costs.

(7) *Maintenance Materials and Labor.* ADL estimated maintenance materials, labor, and upkeep reinvestment at levels which maintain long-range viability of an installation. Items included in this category are those normally expensed by a firm. Capitalized maintenance for replacing and/or modernizing a facility is discretionary and shown separately on an industry aggregate basis. (Appendix F-4.)

(8) *Effluent Control Costs.* ADL used the updated Development Document data as the basis for effluent control costs in all cases. As discussed in Chapter IV, the Development Document estimates are reasonable but are subject to wide variation from mill-to-mill.

g. Slush Pulp Cost

Virgin-fiber kraft pulp is the basis for several paper and board grades as well as for market pulp. Because any combination of drying and papermaking operations may be integrated to kraft pulping, papermaking capacity for a given product is independent of pulp mill capacity. To obtain economies of scale, the pulp mill is generally much larger than a single papermaking operation and typically supports two or more paper machines.

For this reason, it was most convenient to develop a total factory operating cost for bleached kraft slush pulp as a raw material input to a papermaking operation. This base-level slush pulp cost was related to a particular pulp mill capacity (800 ADT/day in the case of bleached kraft) and includes wood preparation, pulping, and bleaching (where applicable). It was determined by subtracting the converting and capital costs allocated to pulp drying from the total factory operating cost in the 800-ADT virgin market-pulp models.

The cost estimates for the papermaking operation include all the supporting operations, such as stock preparation, papermaking, and roll finishing. Associated with the slush pulp are the principal utilities (steam and power generation, water supply, and effluent treatment) related to pulp drying. The investment and operating costs for shared facilities are allocated between the pulping and papermaking operations in proportion to their respective use of the utilities, as indicated in Figure F-1.

In addition to sharing physical facilities integrated papermaking operations also have the benefit of sharing many of the costs included with factory overhead. An overhead schedule was developed for an 800-ADT/day market pulp mill to provide the basis for factory overhead costs on all models integrated to bleached kraft pulping.

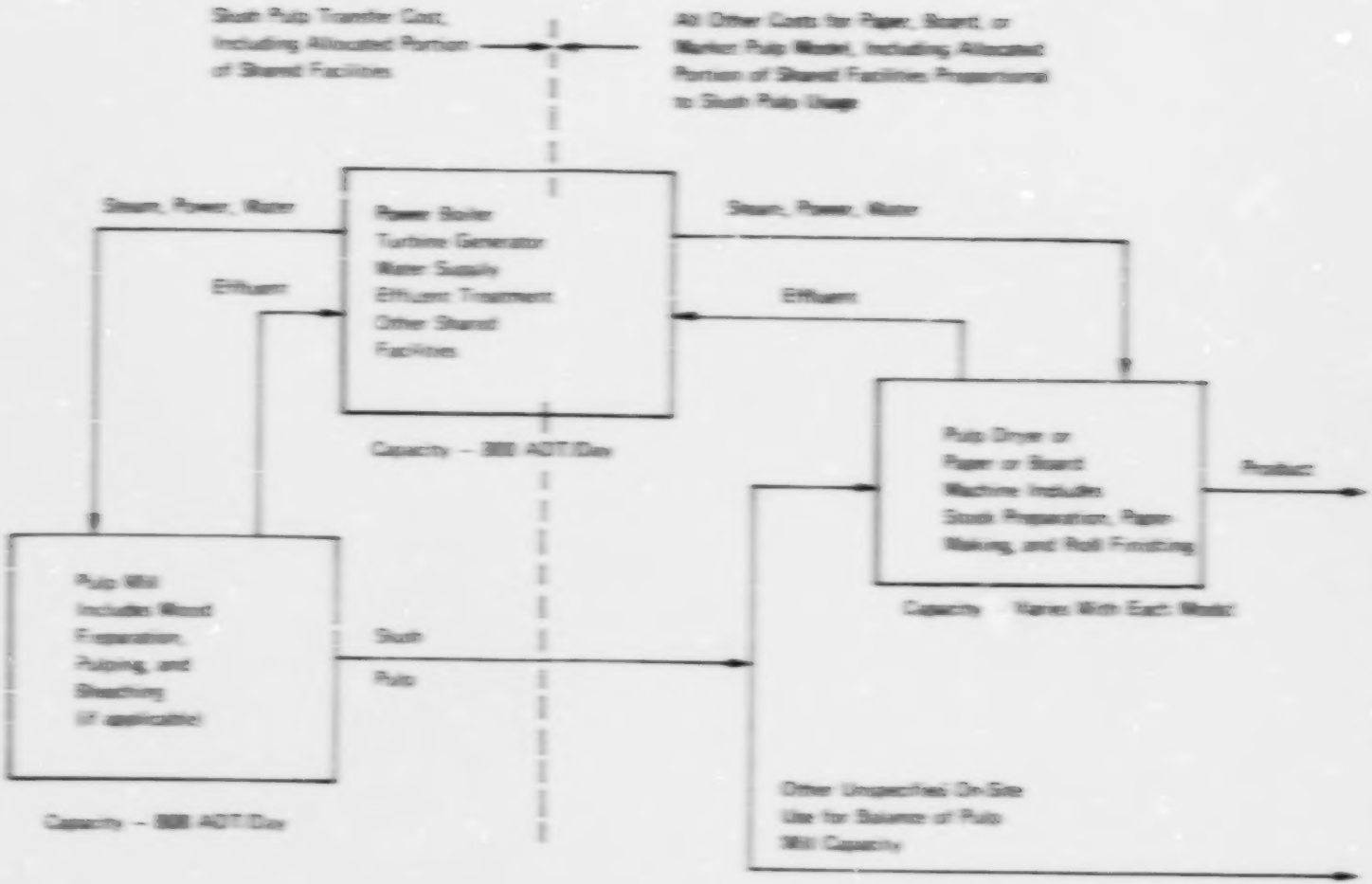
Slush Pulp Transfer Cost, Including Allocated Portion of Shared Facilities
All Other Costs for Paper, Board, or Market Pulp Model, Including Allocated Portion of Shared Facilities Proportional to Slush Pulp Usage
Steam, Power, Water
Effluent
Power Boiler
Turbine Generator
Water Supply
Effluent Treatment
Other Shared Facilities
Capacity -- 888 ADT/Day
Steam, Power, Water
Effluent
Pulp Dryer or Paper or Board Machine Includes Stock Preparation, Paper Making, and Roll Finishing
Capacity -- Varies With Exact Model
Product
Pulp Mill Includes Wood Preparation, Pulping, and Bleaching (if applicable)
Capacity -- 888 ADT/Day
Slush Pulp
Other Unspecified On-Site Use for Balance of Pulp Mill Capacity

FIGURE F-1 DEFINITION OF SLUSH PULP COST AND ALLOCATION OF COST OF SHARED FACILITIES FOR INTEGRATED MILL COMPLEX (BLEACHED KRAFT MODEL)

To calculate the operating costs for a product made on a paper machine smaller than a corresponding pulp mill, ADL transferred the total operating cost of "slush pulp" to the papermaking operation. Slush pulp costs (fiber, labor, utilities, etc.) are treated as a raw material item in the papermaking operating schedule. Similarly, to calculate the *total* investment for the manufacture of a studied product, an apportioned amount of the pulp mill investment (proportional to pulp usage) is added to the estimated investment for the papermaking operation.

Finally, virgin groundwood pulp at 440 ADT/day and semi-bleached kraft softwood pulp at 880 ADT/day are the bases for several paper and board grades. ADL used the same technique of developing a slush pulp transfer cost to an integrated papermaking operation. To obtain total capital requirements, the pulp mill investment associated with the quantity transferred to the papermaking operation was added to the investment for the paper mill.

8. CAPITAL REQUIREMENTS

a. Total Fixed Capital

Total fixed capital is the total of physical plant cost and other fixed capital costs. In the previously referenced source document, a capital cost schedule was developed for each mill model. These estimates were based upon published and in-house information. We believe the estimates have a precision of +25% to −10%; thus, while they are not suitable for making an investment decision, they are adequate for cost comparisons and useful as the basis of estimating capital requirements to support industry expansion.

Capital costs for woodlands operations are not included in any of the estimates. Where a woodlands position exists, its capital and operating costs as well as its profitability are reflected in the cost of wood as delivered to the mill site.

(1) *Physical Plant Cost.* The physical plant cost consists of the direct plant cost plus the estimated costs of construction supervision and overhead, engineering, and allowance for contingencies. Direct plant cost is the installed cost of buildings, purchased equipment, and site work, excluding the cost of land. Each element in the cost schedule includes purchased equipment and building materials, piping, instrumentation, electricals, structures, foundations, and associated labor costs.

(2) *Other Fixed Costs.* ADL also estimated the additional capital cost items that are normally associated with a new venture but not included in the physical plant cost — spare parts, pre-startup and startup costs, project management, etc. Note, however, that interest accruing on borrowing during the construction period is *not* included in the estimated capital costs.

b. Working Capital

Experience has demonstrated that the working capital required for raw materials, goods in process, inventory, and accounts receivable (less accounts payable) is generally equivalent to three months' production at total factory cost.

c. Capital Call-Down Schedule

Table F-2 shows the capital call-down schedule for the construction of new mills. This schedule was used in the economic impact analysis (Chapter VII), to postulate the timely

commitment of capital and the subsequent capital call-down for meeting the industry's need for new capacity. The table also indicates the simplified startup schedule (80% of full production in the first year of operation) used in calculating annual sales revenue.

8. OPERATING COST CONSIDERATIONS

a. Raw Material Requirements

Raw material costs include all raw materials for manufacture, auxiliary materials such as chemicals for water and effluent treatment, and net credit for any by-product recovery.

(1) *Fiber Cost.* Requirements for pulpwood or other cellulosic raw materials were developed via a material balance that took into account such factors as wood densities, pulping yields, and process losses. The total factory operating cost of stush pulp was considered a raw material cost for any papermaking operation integrated to a pulp mill (cost could provide furnish for more than one product line.

(2) *Other Raw Materials.* The material balance also provided estimates of the pulping and papermaking chemical requirements. ADL used typical fresh chemical makeup rates to pulping and bleaching operations but accounted only for the fiber output from these operations. Chemical losses were assumed equal to chemical makeup rates minus any by-product recovery, and no attempt was made to postulate internal chemical recovery and recycling.

Most of the papermaking chemicals become part of the product. ADL thus accounted for papermaking chemical losses and, by difference, for the additives recovered with the finished sheet.

The material balance included other chemical raw materials such as detergents, slimicides, antifoam agents, retention aid's, pitch control agents, and water softening agents (or ion exchange resins) for boiler feedwater treatment. These materials are used in small quantities, but when aggregated they constitute an identifiable component of the manufacturing cost.

All chemical costs are combined under "Other Raw Materials" and reported as a single unit per ton of product. Mill records and ADL experience were used to estimate the total cost.

b. Conversion

Conversion includes all factory labor (direct and indirect), supplies, energy, and expenses other than raw materials or capital-related items.

(1) *Labor, Hourly.* Labor requirements for many of the models are based on in-house information pertaining to actual mill practice; others are based on more thorough pre-engineering cost studies that ADL has prepared for various product areas. A man-year is assumed to consist of 2008 man-hours (47 weeks at 44 hours). Holidays and vacations are included in fringe benefits at 32% (included in hourly rate).

For new plants, the cost of maintenance labor is often estimated as a percentage of plant investment; about 2% is typical for pulp and paper manufacture. However, ADL chose to develop a manning table to estimate this cost, specifically excluding any labor associated with capital improvement or replacement projects.

(2) *Supplies (Operating, Maintenance, and Packaging).* Operating supplies include replaceable parts such as felts, wires, lubricating oil and grease, rags, and fuel (for fork lift trucks). Units and unit costs for this entry are not meaningful. In-house mill records and industry records provide the most reliable source of information on the cost for the various pulp and paper grades.

Maintenance supplies in pulp and paper manufacture typically cost about the same as maintenance labor; they were estimated at 1.5% to 2% of physical plant cost.

Packaging supplies also vary widely among the paper grades selected for economic analysis. For example, linerboard requires only a core, plugs, and steel strapping; the total cost for these supplies is $0.50-$1.00 per ton. The supplies used in packaging tissue, however, which included printed folding boxes and corrugated containerboard, cost about $50 per ton. For most commodity grades, where packaging supplies are a minor item, a single entry is shown based on industry practice. For tissue, including packaging supplies, AIH, separately estimated the cost of converting from jumbo rolls to packaged product.

(3) *Energy.* The unit requirements for fuel and power were derived by an energy balance. Only the portion of the total steam requirement which is generated from fossil fuel represents an actual cost; the portion obtained by burning back or black liquor is transferred from the pulp mill at no charge.

Whenever total steam requirements for a product (including the combination of pulping and the forming for integrated operations) exceeded the equivalent of 5000 kw of power, the cost of an extraction turbine generator was included in the estimated capital requirements. All smaller operations were assumed to use power purchased from external sources.

AIH, did not explore the economics of generating power vs. purchasing power for each model. The minimum 5000 kw for on-site power represents an average for second-quarter 1975 conditions; this minimum would vary from one location to another, depending on regional and local power costs, specific conditions of the mill, and the capital cost of generating facilities.

Since the capital, labor, and chemical treatment costs for water supply were included in the estimates, no purchase costs were included for water.

(4) *Factory Overhead.* Factory overhead includes on-site management; salaried supervision; the salaries of office clerical, technical, and laboratory staff; on-site office and laboratory supplies and expense; and personal expenses. It excludes off-site overhead, such as corporate administration and sales expense, which are shown as separate nonfactory costs. Factory overhead is expressed as a percentage of total direct and indirect labor, excluding maintenance labor.

c. Capital-Related Costs

(1) *Capital Recovery.* Capital recovery is the amount required to repay the initial investment plus the cost of capital, distributed uniformly over the expected life of the project. A value of 12.1% of the fixed capital requirement was used as the capital recovery rate. (See Chapter VI for derivation of capital recovery rate.)

(2) *Local Taxes and Insurance.* Local taxes on new facilities are typically 2 to 2½% of new investment, a contribution to operating cost which can be derived readily.

d. Cost of Sales

(1) *General Sales and Administrative Costs.* General administration includes all allocated corporate (nonfactory) costs, such as central engineering, purchasing, research, corporate management and legal staff, and office overhead. This cost is affected by corporate structure, size of the operation, and value of the product, and ranges typically from about 3% to 10% of the total factory cost. (This cost varies widely, however, and is strongly dependent upon the marketing characteristics of the individual product. ADL relied upon its experience to select a typical cost for this item for each of the studied paper and paperboard products.)

Sales expense for commodity products, such as linerboard, newsprint, or bag paper, is significantly less than that for retail-oriented products such as tissue, printing paper, and writing paper. Moreover, there is a wide variation within each major category, reflecting the costs associated with marketing brand-name or private-label products. ADL used its judgment to select an appropriate value from within the range of costs experienced by the industry.

(2) *Freight Out.* The cost of shipping the finished product has been estimated for individual products. Variations in freight rates reflect differences in product value, the industry practice of exchanging some board grades between manufacturers, or distribution patterns based on paper grades and mill size. Again, general industry averages were used.

4. SUPPLEMENTARY USES OF NEW MILL MODELS

In addition to showing how the costs of compliance are related to direct manufacturing costs, the new mill models provide a convenient data base for estimating two other key inputs required in the economic impact analysis: (a) the capitalized maintenance required for the existing industry, and (b) the capital investment required to build additional industry capacity. These items are not germane to Chapter III, which pertains only to the costs of compliance; they are used in Chapter VI, which deals with the industry's capital needs during the studied period.

a. Capitalized Maintenance

Capitalized maintenance for rebuilding or replacing existing equipment constitutes a major portion of a mill's or corporation's budget. These capitalized expenditures are over and above routine maintenance costs, which are expensed and appear as part of the operating cost schedules. The expenditures may constitute a significant percentage of the industry's total capital budget; thus, it is essential to make a reasonable estimate of them.

As a starting point, the average normal life of pulp and paper equipment, given only routine expensed maintenance, is about 40 years. This means that on average, 2½% of existing capacity becomes mechanically obsolete each year. The current high rate of research and commercial development should increase the rate of technical and economic obsolescence; thus an overall average of 3% of existing capacity becoming obsolete each year for technical or mechanical reasons (and without further investment) is reasonable over the studied period in this report.

The estimated 3% obsolescence constitutes the *total* requirement of the industry's tonnage if capitalized maintenance is not provided to rebuild or replace existing capacity. However, capacity retirement over this period was estimated at about ½% per year; hence, capitalized

maintenance associated with the assumed requirements must be deducted from the estimated capital requirement. Therefore, the remaining 2½% (roughly 1.7 million tons) must be replaced each year if the industry is to remain at the assumed capacity.[2]

Basing the replacement cost solely on the new mill cost models would overstate the capital requirement. If we assume that the costs associated with new grassroots plants can be reduced by some 25% by a mix of new machines at existing sites and other improvements, the replacement rate is further reduced from 2½% to 2% of the cost of a new mill. This is *not* a reduction in replacement tonnage; it is simply a reduction in *capital requirements*.

Hence, for estimating the annual capitalized maintenance associated with replacing 2% of the industry capacity, API, used 2% of the capital costs of the corresponding new mill model(s). The resultant estimate corresponds to about $881 million, or about $13 per ton of industry process capacity. Note that these estimates are predominantly for maintaining productive equipment, but do include a proportional share (based on the new mill cost models) of capitalized maintenance on air and water control equipment.

b. Capital Investment for Additional Capacity

The industry does not build all its additional capacity in the form of new grassroots facilities; much capacity is added by incremental expansion of existing equipment or the installation of new machines at existing sites. Accordingly, to estimate the industry's capital requirements for additional capacity, it is necessary to postulate: (a) how much additional capacity will be obtained by each method and (b) the capital requirement associated with each of the methods used. These two considerations are further discussed below.

(1) *Relative Importance of Methods for Adding Capacity*

In 1968, a year of rapid capacity expansion typical of the 1965-1970 period, new capacity amounted to some 2.8 million tons per year, with:

- 49%: new grassroots facilities,
- 22%: new machines at existing sites, and
- 28%: other incremental expansion.

More recently, API has projected an average expansion rate of 1.5 million tons per year through the period of 1976 to 1978. This increase will be achieved as follows:

- 7%: new grassroots facilities,
- 45%: new machines at existing sites, and
- 48%: other incremental expansion.

The rate of new grassroots construction in 1976 to 1978 is low because of rapid escalation in capital requirements and restricted availability of new mill sites. Conversely, the rate in 1968 reflected a period of rapid expansion in the South to utilize the wood resources and mill sites that were readily available then. Because of the lower unit cost for incremental expansion of an existing machine, it is the route preferred by industry. However, API, does not believe that the industry can indefinitely maintain the high (48%) level achieved in the 1976-1978 period.

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2 The net industry capacity (after 1½% per year retirement) was estimated at 61.6 million tons for 1977 and 60.0 million tons for 1983; see Tables III-1 and -2.

The extent to which the output of existing machines can be increased is finite and subject to emerging technology. ADL believes that the level experienced in 1968 is more representative of long-range opportunities for incremental expansion of existing machines.

Accordingly, for purposes of estimating industry capital requirements (Chapter VI), ADL believes the following expansion schedule is reasonable:

1976-1979:
- 10% new grassroots facilities,
- 40% new machines at existing sites, and
- 50% other incremental expansions.

After 1979:
- 25% new grassroots facilities,
- 50% new machines at existing sites, and
- 25% other incremental expansions.

The expectation that half of all additional capacity will be obtained by the installation of new machines at existing plant sites is consistent with present plans and also with projections of continuously improving wood yields from existing commercial forests through improved management, growing, and harvesting techniques.

(2) *Unit Cost for Additional Capacity*

The new mill models provide a convenient point for estimating the costs of the previously listed methods of expansion. New grassroots construction clearly is the most expensive of the three methods. It is not unreasonable to postulate that a 15-20% saving would be achieved by adding a new machine at an existing site and utilizing existing common facilities such as administration buildings, laboratory facilities, machine shop, stores, and shipping and receiving areas.

Similarly, compared with the cost of new grassroots facilities, incremental expansion of an existing machine would require perhaps 30-40% as much capital. Obviously, these estimates are imprecise and vary widely among individual mills. Nevertheless, for overall "industry averages," ADL believes the following are reasonable comparisons of capital cost for adding new capacity via the alternative techniques:

% of New Grassroots Capital Cost	Method
100	New grassroots facility
85	New machine at existing site
35	Other incremental expansion

Based upon the percentage mix of the alternatives previously identified for 1976-1979, the weighted average cost for replacement or additional industry capacity is about $450 per annual ton. The average cost for new capacity increases after 1977, since ADL believes the number of opportunities to increase capacity via the more economical incremental expansion at existing sites will decline in relation to the more costly new grassroots facilities and new machines.

If the capital costs for new grassroots facilities were used alone, the figure would be $650 per annual ton. Applying these capital cost estimates to the existing industry's 68.97 million tons of capacity results in a replacement cost of $30 billion and $45 billion, respectively.

These estimates are presented only for purposes of information and for documentation of the approximate capitalized maintenance costs stated in Subsection 4.a. The detailed capital requirements used in the impact analysis are estimated on the basis of separate calculations and projections for each product sector derived above and thus may differ slightly from the overall industry averages.

APPENDIX G

FIELD INTERVIEW GUIDE FOR MILL CLOSURE ANALYSIS

Date:_____

I. Description of Contact[1]

- name and title of person contacted:
- company:
- location of subject mill and process/product category:

II. Identification

- of interviewer — of Arthur D. Little, Inc.

III. Purpose of Call

We are currently doing a study for the EPA on the economic impact of Federal pollution regulations on the pulp and paper industry. In this study, we must screen those mills where we have questions on their ability to meet EPA *water* effluent control guidelines stipulated for 1977 and 1983. I am calling you to obtain your insight and judgment concerning the future viability of your mill(s). (identify)

The information that you contribute to our study will be combined with other inputs in statistical summaries. It will not be identified specifically with your mill or company.

IV. Current Status of Mill

- daily capacity: Pulp____; Products _____
- pollution control
- equipment in place:
- age of mill:
- number of employees: Production___ ; Administrative: _____
- how well has mill been maintained?
- are there any exceptional economic conditions facing the mill?
- operating cost advantages/disadvantages:
  - raw material supply arrangements
  - energy costs
  - production efficiencies
  - other

1. Contacts should be as highly placed as possible. Ideally, the president of small (one mill) companies and the corporate officer of large (multi-mill) companies should be contacted.

Pages 166 and 167 are blank.

V. Pollution Control Cost Situation[1]

- Does existing water pollution control equipment comply with 1977 EPA standards; 1983 EPA standards?
- If the answer above is negative, what is required to achieve full compliance?
- How much will it cost?
- Where will the required capital come from; at what anticipated interest rate?
- What financial impact do you expect on:
  - mill operating costs
  - mill profitability
- Have you tried to justify this pollution control expenditure on a return-on-investment basis?
- Is there any possibility of municipal treatment tie-in? At what cost?

VI. State/Local Pollution Control Requirements

- Beyond EPA requirements, what state/local air and water pollution control requirements exist?
- What additional economic impact will state/local requirements have on your operations?

VII. Future Plans

- What plans do you have to invest further in:
  - pollution control equipment
  - expansion
  - mill maintenance
- Are there any plans to shift product mix?
- Will executing these plans achieve full compliance with EPA standards?
- Are there any plans to curtail operations?
  - partial
  - complete closure
  - if complete closure is foreseeable, what is your estimate of mill salvage value?

VIII. For Multi-Mill Companies Only

- Are there plans to shift capacity and/or personnel from this mill to other mills in the company?
- Are there other mills in your company (beyond those that we have discussed) that you think may have difficulty complying with EPA pollution control standards?

1/ Interviewer should have a copy of EPA effluent standards by process sector, since it may be necessary to compare current and stipulated effluent loadings.

APPENDIX H

SUPPORTING DATA FOR CAPITAL IMPACT ANALYSIS

1. FLOW OF FUNDS MODEL

a. Model Equations

The basic equation underlying the analysis of capital requirements is the valuation model

$$\text{Initial Equity} = \sum_{t=1}^{N} \frac{CF_t}{(1+r)^t} + \frac{(\text{Final Equity} - UCA_N)}{(1+r)^N} \qquad (1)$$

where

- r = required rate of rate of return on equity
- CF_t = cash flow to equity in period t
- N = number of periods in analysis (=8)
- UCA_N = Uncommitted cash assets (i.e., accumulated cash in excess of operating requirements not yet distributed to stockholders) held at end of period N.

The cash flow to equity in each period is defined as

$$CF_t = P_tQ_t - COE_t + D_t - DA_t - \Delta WC_t - INV_t - INT_t - TAX_t \qquad (2)$$

where

- P_t = product price in period t
- Q_t = product sales volume in physical units in period t
- COE_t = cash operating expense in period t (exclusive of interest and taxes)
- D_t = new debt raised in period t
- DA_t = debt amortized in period t
- ΔWC_t = net increase in working capital in period $t = WC_t - WC_{t-1}$
- WC_t = $OCB_t + INVENT_t + REC_t - PAY_t$
- OCB_t = operating cash balance held in period t
- $INVENT_t$ = inventories held in period t
- REC_t = accounts receivable held in period t
- PAY_t = accounts payable accrued through period t
- INV_t = capital investment in period t

Pages 170 and 171 are blank.

INT_t = interest paid in period t

TAX_t = Federal income tax payable in period t

= $TP_{t-1} + H_t - TP_t$

TP_t = Federal income tax payable at end of period t

= αH_t

H_t = Federal income tax incurred in period t

= $r(P_tQ_t - COE_t - DEP_t - INT_t - TSCF_t) - TSCR_t$

r = Federal income tax rate = 48%

DEP_t = depreciation deduction for tax purposes taken in period t

$TSCF_t$ = tax loss carryforward utilized in period t

$TSCR_t$ = investment tax credit utilized in period t

The model treats P_t as control variable and sets the value of P_t to satisfy equation (1). Further, flow of funds balance implies that

$$CF_t = DIV_t + \Delta UCA_t - E_t \qquad (3)$$

where

DIV_t = dividends paid in period t

ΔUCA_t = increase in uncommitted cash assets in period t

E_t = new equity raised in period t

Consequently, the model also calculates external financing, through the equation

$$\begin{aligned} EF_t &= D_t + E_t \\ &= \Delta WC_t + INV_t + DA_t + DIV_t - (P_tQ_t - COE_t - INT_t - TAX_t) + \Delta UCA_t \end{aligned} \qquad (4)$$

that is, as the difference between required outlays of funds and the funds available from operations or from the liquidation of uncommitted cash assets.

b. Parameters and Assumptions

(1) Parameter Values Based on Financial Analysis

The first step in estimating the parameters of the equations described above was a financial analysis of the 49 companies listed in Table H-1. As was described in Chapter VI, the historic statements were adjusted to eliminate woodlands and converting operations and other businesses extraneous to primary pulp and paper manufacturing, and then were normalized to total primary pulp and paper sales volume. Tables H-2, H-3, and H-4 present the resulting estimated balance sheets, operating statements, and sources of funds for the U.S. primary pulp and paper industry for the period 1966-1975.

TABLE II-1

COMPANIES INCLUDED IN INDUSTRY COMPOSITE

Bergstrom Paper Company
Brown Company
Chesapeake Company
Clevepak Corporation
Consolidated Papers
Crown Zellerbach
Federal Paperboard Company
Fibreboard Corporation
Fort Howard Paper Company
Glatfelter Company
Great Northern Nekoosa Corporation
Hammermill Paper Company
Hudson Pulp and Paper Corporation
Inland Container Corporation
International Paper Company
Kimberly-Clark Corporation
Longview Fibre Company
Mead Corporation
Mosinee Paper Corporation
OlinKraft
Pentair Industries
Potlatch Corporation
St. Regis Paper Company
Scott Paper Company
Sonoco Products Company
Borg Paper Company
Southland Paper Mills
Stone Container Corporation
Union Camp Corporation
Westvaco Corporation
Whippany Paper Board Company

TABLE A-1

PRO-FORMA BALANCE SHEET OF THE U.S. PULP, PAPER, AND PAPERBOARD INDUSTRY
(EXCLUDING ACQUISITIONS AND COMPETITIVE EXPANSIONS)
FOR THE PERIOD 1966-1975
(Millions of Current Dollars)

ASSETS	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966
Cash	1,153	1,422	1,347	807	411	434	488	525	423	480
Receivables	1,795	1,878	1,672	1,593	1,451	1,517	1,443	1,284	1,093	1,030
Inventories	2,351	2,438	1,799	1,655	1,779	1,820	1,862	1,535	1,408	1,343
Total Current Assets	5,299	5,738	4,818	4,055	3,641	3,771	3,843	3,344	2,925	2,852
Gross Plant	18,701	17,593	15,485	14,488	14,487	14,573	13,801	13,523	12,325	11,142
Accumulated Depreciation	(8,500)	(8,118)	(7,871)	(7,518)	(7,136)	(7,021)	(6,587)	(6,344)	(5,754)	(5,372)
Net Plant	10,151	9,875	7,614	7,376	7,351	7,552	7,214	7,179	6,571	5,770
Other Assets	1,457	1,640	1,534	1,317	1,380	1,426	1,307	1,240	948	791
Total Fixed Assets	11,608	11,715	9,158	8,693	8,731	8,978	8,521	8,419	7,519	6,561
Total Assets	16,907	16,453	13,976	12,742	12,373	12,749	12,364	11,763	10,444	9,414
LIABILITIES AND EQUITIES										
Accounts Payable	996	737	657	578	526	541	507	NA	NA	NA
Miscellaneous Accruals	832	775	571	472	425	479	449	NA	NA	NA
Short-Term Debt	174	238	62	75	132	282	401	NA	NA	NA
Current Portion of Long-Term Debt	168	102	60	84	88	134	106	NA	NA	NA
Total Current Liabilities	2,402	1,448	1,766	1,352	1,260	1,481	1,566	1,266	1,174	905
Long-term Debt	5,021	4,636	4,103	3,840	3,738	3,650	3,103	3,230	2,738	2,346
Deferred Taxes	1,013	971	822	710	656	639	605	494	444	361
Total Liabilities	8,436	8,055	6,691	5,902	5,654	5,770	5,274	4,990	4,186	3,612
Equity	8,371	8,398	7,285	6,840	6,719	6,979	6,890	6,773	6,258	6,102
Total Liabilities and Equities	16,807	16,453	13,976	12,742	12,373	12,749	12,364	11,763	10,444	9,414

TABLE B-3

PRO-FORMA OPERATING STATEMENT OF THE U.S. PULP, PAPER AND PAPERBOARD INDUSTRY
(INCLUDING WOODLANDS AND CONVERTING OPERATIONS)
FOR THE PERIOD 1966-1975
(Millions of Current Dollars)

	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966
Sales	15,610	17,384	13,684	11,701	10,685	10,427	10,335	9,503	8,844	8,712
Cost of Goods Sold	11,234	12,516	9,867	8,652	7,973	7,424	7,424	6,840	6,336	6,020
General, Selling and Administrative Expense	1,747	1,828	1,617	1,470	1,404	1,361	1,264	1,137	1,038	979
Depreciation	895	541	745	707	696	675	648	625	570	533
Pre-Tax Operating Income	1,753	2,369	1,475	872	612	744	1,807	901	1,030	1,180

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The historic analysis was used to estimate:

- Initial balance sheet structure,
- Manufacturing costs of the existing industry,
- Behavior of G&A expenses,
- Behavior of the working capital accounts, and
- Dividend and tax payment policy.

(a) Initial Balance Sheet Structure

The initial values of the accounts are set forth in the 1975 column of Table II-2. In addition, the analysis indicated that the depreciation charges on existing net plant were well approximated on a 10-year straight-line basis for book purposes, and on an 8-year straight-line basis for tax purposes. The embedded cost of existing debt averaged 7%. AIH, used a debt amortization schedule for the period 1976 to 1980 corresponding to the 32-company composite, and used a level amortization rate for the period 1981 to 1983 corresponding to the average rate between 1976 and 1980 of 7% per annum of non-current long-term debt existing at the end of 1975.

(b) Manufacturing Cost of Existing Industry

As was mentioned in the text, changes in real operating costs rendered the use of regression methods to split the fixed and variable components of existing plant manufacturing costs inappropriate. Hence, AIH, performed the following algebraic analysis to determine cost parameters, based only on 1975 manufacturing cost (i.e., cost of goods sold, in the 1975 column of Table II-3):

Let the underlying cost equation of the existing industry be

$$C/O/G/S_{75} = f \cdot C_{75} + v \cdot P_{75}$$

where

$C/O/G/S_{75}$ = cost of goods sold during 1975

f = unit fixed cost per ton of installed capacity

C_{75} = capacity in place at end of 1975

v = unit variable cost per ton of product produced

P_{75} = tonnage produced during 1975

Define

s = unit total cost of goods sold in 1975

$$= \frac{C/O/G/S_{75}}{P_{75}} = \frac{f}{OR_{75}} + v$$

where

$$OR_{75} = \frac{P_{75}}{C_{75}} = \text{operating rate in 1975}$$

Let

$$\phi = \text{operating leverage factor}$$

$$= \frac{\text{fixed component of } C/O/G/S \text{ at full production}}{\text{total } C/O/G/S \text{ at full production}}$$

$$= \frac{f}{f+v}$$

Now assume ϕ is the same for the existing industry as for an average of new mill models weighted by 1975 production in each sector.[1] Then the unit fixed and variable manufacturing costs can be computed as

$$f = \frac{\frac{\phi}{1-\phi} \cdot s}{\frac{\phi}{(1-\phi)(OR_{-1})} + 1}$$

and

$$v = \frac{s}{\frac{\phi}{(1-\phi)(OR_{-1})} + 1}$$

(c) Behavior of General, Selling, and Administrative Expenses

General, Selling, and Administrative Expenses tend to track generally with the average level of sales volumes, but cannot be adjusted rapidly to sales volume fluctuations, and so they each have a significant fixed component. Therefore, ADL estimated these expenses using a simple regression equation based on current dollar values. The equation used was:

$$GS\&A = 310 + 0.0817 \times \text{Sales (\$ million current)}$$
$$(t = 8.86)$$

$R^2 = 91\%$
$F = 78.5$
D.W. = 0.75

and while the residual serial correlation is significant, the fit is adequate for present purposes.

(d) Behavior of Working Capital Accounts

The definition of working capital used in this analysis excludes the component of short-term financing corresponding to miscellaneous accruals. This definition is conservative in that it may slightly overstate the permanent financing needs of the industry. ADL used a narrow definition, because the miscellaneous accrual account has behaved peculiarly over time and thus could not be forecasted reliably.

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1. The fixed component of cost in the new mill models presented in Appendix F was identified as:

15% of fiber cost	100% of capital related charges
50% of labor	25% of water effluent and air emission control operating expenses
50% of energy	75% of OSHA noise control expenses
100% of factory overhead	

Figure H-1 presents the historic behavior of the working capital accounts. The current asset accounts are cyclical, and so were estimated at their dollar-weighted average levels of:

- Operating cash balance = 27 days cash operating cost (excluding interest and taxes);
- Receivables = 48 days sales; and
- Inventories = 55 days sales.

Accounts payable exhibited a sudden jump in 1975, after a long period of stability. ADL has assumed that this shift represents a shift in the terms of trade credit, and has forecasted accounts payable using the 1975 value of:

- Accounts payable = 28 days cash operating cost.

This assumption has no material impact on any results presented.

(c) Dividend and Tax Payout Policy

Because dividend payout and tax payment scheduling are determined at the corporate level, ADL based its assumptions on the behavior of the unadjusted 32-company composite. For the composite, dividend payout averaged 40% of after-tax income over the historic period, and taxes payable averaged 40% of taxes incurred; therefore, these values were used throughout the analysis.

(2) Parameter Values Based on Demand Forecasts

The only parameter directly dependent on the demand forecast is quantity produced. The first step in the production forecast is an initial econometric forecast of U.S. pulp, paper and paperboard demand (excluding dissolving pulp) based on the aggregate model equation (1) presented in Appendix G, assuming 1975 prices and an overall level of macroeconomic activity corresponding to one of the Chase Econometric scenarios. Table H-5 presents the three initial demand forecasts used in the study. Demand is then converted to production through the equation

$$\text{Production} = (0.93 \times \text{Demand}) + 1307$$

which represents an assumed net import level of 7% of consumption and a constant rate of production of dissolving pulp.

The demand and production forecasts are then iteratively adjusted to reflect the impact of forecast price changes as described in the text.

(3) Parameters Values Based on Capacity Forecasts

The model parameters directly dependent on capacity forecasts are: the levels of capital investment for incremental expansion, replacement and major maintenance, and the weights used to determine average manufacturing costs. The basic unit capital and operating cost parameters have been discussed above in this Appendix and in Appendix F. Therefore, it remains only to present the actual capacity forecasts and the adjustment factors used to account for the three possible modes (i.e., grassroots, new machines, and improvements) of introducing incremental and replacement capacity.

FIGURE II-1. COMPONENTS OF WORKING CAPITAL

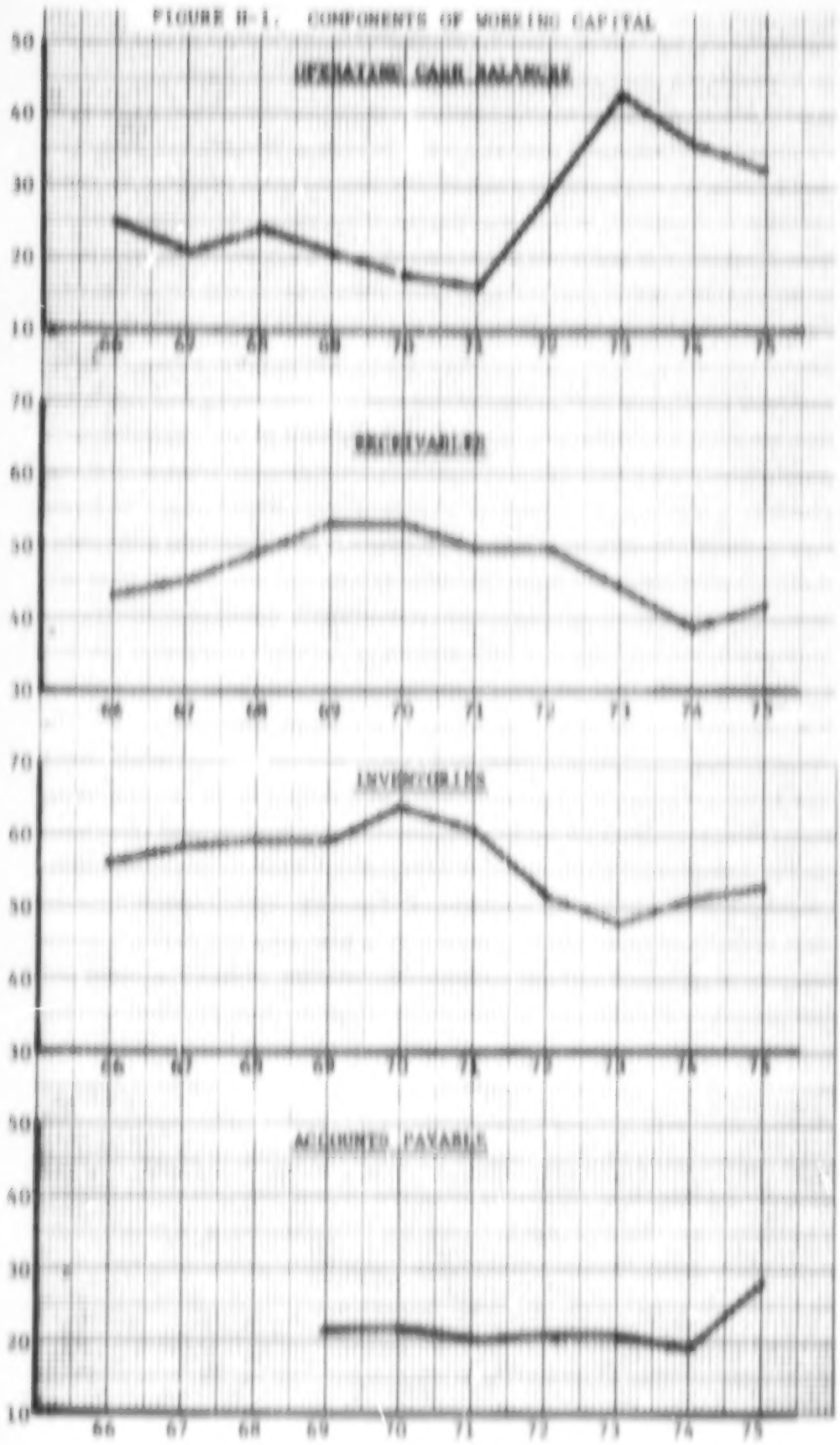

TABLE II-5

FORECAST U.S. DEMAND FOR PULP AND PAPER (EXCLUDING DISSOLVING PULP)
UNDER ALTERNATIVE GROWTH RATE ASSUMPTIONS ASSUMING 1975 REAL PRICES

Year	LOW GROWTH[1]		MODERATE GROWTH[2]		HIGH GROWTH[3]	
	Index of Industrial Production	Pulp and Paper Demand (000 Tons)	Index of Industrial Production	Pulp and Paper Demand (000 Tons)	Index of Industrial Production	Pulp and Paper Demand (000 Tons)
1976	125.5	59,500	125.5	59,500	125.5	59,500
1977	136.8	63,900	136.8	63,908	136.8	63,908
1978	134.1	62,854	135.6	63,440	140.8	65,157
1979	131.1	62,685	132.5	62,730	144.8	66,717
1980	139.6	65,000	139.6	65,000	153.7	70,501
1981	153.7	70,501	153.7	70,501	164.5	74,725
1982	164.5	74,725	164.5	74,725	173.4	78,187
1983	173.4	78,187	173.4	78,189	180.7	81,035
Average Growth (%/Year)						
1976-1983	4.7	3.8	4.7	3.8	5.3	4.5
1976-1983	3.9	1.9	3.9	1.9	4.5	2.3

[1] Chase Econometrics (CE) Forecast

[2] Chase Econometrics Forecast, assuming increased Federal spending to mitigate recession in 1978-1979

[3] Chase Econometrics Forecast, assuming no recession in 1978-1979

(a) Capacity Levels

Tables H-6A through H-6C present the assumed year-end capacities for each of the major product sectors for each of the three capacity growth rate scenarios considered, which correspond to the growth rate ranges presented in Table IV-17. Tables H-7A and H-7B present the assumed year-end values (for each of the product sectors) of capacity which was included in the industry as of the end of 1975 — that is still in place. Table H-7A presents these values assuming no water effluent control standards are in effect, so that only normal retirements occur. Note that Tables H-6 and H-7 incorporate some additional detail on product sector growth and retirement rates over that presented in the main text. The tables also include a sector labeled "Miscellaneous Products," which has been introduced as a balance item, and is treated as behaving like a weighted average of all other sectors excluding dissolving pulp.

(b) Adjustments for Alternative Sources of New Capacity

Table H-8 presents distributions of new capacity (incremental plus replacement) installed in the "grassroots," new machine, and on-site improvement modes used in the analysis, and the relative capital costs compared to the new mill models used for each mode. Relative capital costs were determined by engineering estimation; the model distributions were based on the following considerations:

In 1968, a year of rapid capacity expansion typical of the period, new capacity amounted to some 2.8 million tons per year, with:

40%: new grassroots,
22%: other new machines, and
38%: other improvements.

For the period 1976 to 1978, the API has announced an average expansion rate of 1.5 million tons per year, with:

7%: new grassroots,
45%: other new machines, and
48%: other improvements.

The high rate of "other improvements" from 1976 to 1978 is probably typical of what the industry prefers, but it is doubtful whether this can be sustained indefinitely. The opportunities for improvement of existing machines are finite and subject to emerging technology. AEH, believes that the 28% level of 1968 is more representative of long-range opportunities for machine improvement, and therefore has projected 25% of expansion beyond 1979 to be through improvements.

The low rate of new grassroots expansion from 1976 to 1978 is indicative of the rapid escalation in capital requirements and the restricted availability of new mill sites. Conversely, the rate in 1968 represented a period of rapid expansion in the South to utilize then readily available wood resources and mill sites. AEH, believes that an intermediate level for new grassroots capacity, estimated at 25% of total expansion, is consistent with industry requirements and capabilities in the long run.

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TABLE B-6C

FORECAST CAPACITY OF THE U.S. PULP AND PAPER INDUSTRY
FOR THE PERIOD 1976-1985 ASSUMING LOW CAPACITY GROWTH RATE
(thousand tons)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Unbleached Kraft Linerboard	16,320	16,870	17,330	17,830	18,350	18,890	19,430	19,940	20,570	21,170
Unbleachd Kraft Bag Paper	4,540	4,540	4,550	4,600	4,640	4,690	4,730	4,780	4,830	4,880
NSSC Corrugating Medium	4,760	4,910	4,945	5,120	5,300	5,480	5,670	5,870	6,080	6,290
Recycled Linerboard	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500	7,500
Jute Linerboard	979	987	996	1,100	1,027	1,043	1,060	1,077	1,094	1,111
Boyce Medium	3,225	3,243	3,267	3,319	3,375	3,427	3,483	3,539	3,596	3,652
Gypsum Linerboard	2,636	2,679	2,699	2,742	2,788	2,831	2,877	2,924	2,970	3,017
SBS Board	5,290	5,360	5,360	5,670	5,780	5,900	6,020	6,140	6,260	6,380
Bond Paper	4,581	4,650	4,817	4,957	5,106	5,259	5,417	5,579	5,746	5,919
Book Paper	7,869	8,040	8,260	8,525	8,771	9,034	9,304	9,584	9,872	10,168
Tissue	4,140	4,231	4,267	4,331	4,394	4,458	4,539	4,596	4,667	4,739
De-inked Tissue	420	429	433	439	446	452	461	466	473	481
Newsprint	3,619	3,691	3,737	3,791	3,843	3,899	3,963	4,026	4,090	4,144
Recycled Newsprint	381	389	393	399	405	411	417	424	430	436
Dissolving Pulp	1,820	1,820	1,820	1,820	1,820	1,820	1,820	1,820	1,820	1,820
Miscellaneous Products	5,790	5,760	5,785	5,960	6,140	6,324	6,515	6,709	6,909	7,114
TOTAL	68,670	70,130	71,360	73,102	74,667	76,417	78,206	80,021	81,907	83,831

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TABLE B-78

1975 CAPACITY OF THE U.S. PULP AND PAPER INDUSTRY STILL IN PLACE
AT END OF YEAR FOR THE PERIOD 1976-1985
ASSUMING WATER POLLUTION CONTROL INDUCED CLOSURES IN 1983

(thousand tons)

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Unbleached Kraft Linerboard	14,824	14,824	14,824	14,824	14,824	14,824	14,824	14,824	14,824	14,824	14,824
Unbleached Kraft Bag Paper	4,510	4,510	4,510	4,510	4,510	4,510	4,510	4,510	4,510	4,510	4,510
NSSC Corrugating Medium	4,148	4,535	4,411	4,381	4,351	4,321	4,291	4,261	4,261	4,232	4,203
Recycled Linerboard	2,500	2,453	2,422	2,344	2,376	2,353	2,330	2,308	2,220	2,176	2,133
Jute Linerboard	942	935	931	929	926	923	920	918	907	902	897
Bogus Medium	3,090	3,072	3,060	3,051	3,047	3,033	3,024	3,015	2,981	2,964	2,947
Gypsum Linerboard	2,553	2,539	2,529	2,520	2,523	2,506	2,499	2,491	2,463	2,448	2,434
SBS Board	5,230	5,230	5,230	5,230	5,230	5,230	5,230	5,230	5,230	5,230	5,230
Bond Paper	4,442	4,433	4,329	4,330	4,317	4,304	4,294	4,269	4,211	4,203	4,196
Book Paper	7,430	7,427	7,426	7,427	7,418	7,394	7,380	7,369	7,233	7,221	7,209
Tissue	4,040	4,040	4,042	4,042	4,040	4,039	4,039	4,038	4,030	4,029	4,028
De-Inked Tissue	421	421	420	420	420	420	420	420	409	409	409
Newsprint	3,549	3,530	3,520	3,487	3,453	3,422	3,389	3,358	3,330	3,296	3,260
Recycled Newsprint	374	370	370	367	364	360	357	353	350	347	344
Dissolving Pulp	1,821	1,808	1,821	1,776	1,735	1,727	1,724	1,711	1,711	1,703	1,695
Miscellaneous Products	5,780	5,749	5,722	5,692	5,649	5,621	5,593	5,567	5,532	5,507	5,482
TOTAL	64,242	65,955	65,434	65,164	65,033	64,867	64,700	64,538	63,792	63,599	63,408

TABLE H-6

ASSUMED DISTRIBUTIONS AND COSTS OF ALTERNATIVE
SOURCES OF NEW CAPACITY IN THE U.S. PULP AND PAPER INDUSTRY
1976-1985

Source of New Capacity	Percent of Total Incremental and Replacement Capacity 1976 - 1979	Percent of Total Incremental Capacity 1980 - 1985	Applicable Percent of New Mill Model Capital Cost
"Greenfield"	10	25	100
New Machines	40	50	85
On-Site Improvements	50	25	35

The remaining 50% of expansion through new machines at existing plant sites is consistent with present plans and also with projections of continuously improving wood yields from existing commercial forests through improved management, growing, and harvesting techniques. In effect, the present expansion through new machines is typical of new greenfield expansion. While this may be desirable, it is not typical of historical industry characteristics and cannot be sustained because of finite limits on the opportunities for expansion.

(4) Depreciation and Tax Assumptions

As has been mentioned above, existing industry depreciation was estimated on a straight-line basis, over ten years for book purposes and over eight years for tax purposes. Depreciation for incremental expansion, replacement, and major maintenance was calculated assuming a 16 year average depreciable life. Book charges were made on a straight-line basis; tax charges were made using a double-declining-balance basis, with a switch-over to straight-line in the first year in which the straight-line charges would exceed the double-declining-balance charge. In addition, all equipment was assumed to be eligible for a 10% investment tax credit. The tax credit was applied as a direct offset to income taxes, subject to the restriction that the credit not reduce taxable income by more than 50%. Unused investment credits were carried forward for a maximum of five years.

AFII did not use the alternative depreciation option for pollution control equipment of a five-year, straight-line write-off with no investment tax credit. The use of this option would have slightly decreased the effective tax rate and thus have slightly decreased the forecast external financing burden. A recent change in the Federal income tax code -- which allows the option of using both a five-year, straight-line write-off *and* a 5% investment tax credit -- would reduce the forecast external financing burden somewhat more.

(5) Future Debt Cost Assumption

The estimation of future interest rates on long-term debt is subject to many of the same problems as is the estimation of future equity costs. Professor Pogue's analysis assumes that the risk-free rate for the period 1978 to 1983 will average about 7.6%. It is difficult to determine the premium over this rate that the debt market will demand from the industry, or what portion of the rate is attributable to inflationary expectations. For this analysis, ADL assumed an interest rate on new debt of 9.5%, which has been typical of new corporate issues over the last few years. The results of the analysis are not very sensitive to this assumption.

B. AGGREGATE EXTERNAL FINANCING MODEL

To forecast the total level of external financing in the private sector of the U.S. economy over the period 1978 to 1983, ADL developed a simple regression model based on annual data for the period 1955 to 1980. The structural equation was based on current dollars, which is particularly appropriate for such an analysis; forecast current dollar results were then adjusted by the GNP implicit price deflator to a 1975 dollar basis.

The current dollar estimating equation was

$$\text{EXFIN} = -4.58 + 0.836\,\text{GPDNR} - .86 \times \text{PROFIT} + 2.97 \times \text{INT}$$

$$(t=)\quad (2.3)\quad (11.5)\qquad (6.1)\qquad (3.9)$$

$$R^2 = .96$$

$$D.W. = 2.0$$

$$s.e.e. = 1.43$$

where

- EXFIN = Corporate issues of long-term debt, preferred stock, and common stock in billions of current dollars
- GPDNR = Gross private domestic investment in non-residential structures in billions of current dollars
- PROFIT = Total corporate after-tax profits in billions of current dollars
- INT = Interest rate on prime commercial paper.[2]

The quality of the fit is very good: the percentage of variation explained is high; all coefficients have the expected signs; all coefficients are significant; and serial correlation of residuals is absent.

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2 The commercial paper rate was used as a proxy for the rate on long-term debt because no long-term debt interest-rate forecasts were available from Chase Econometrics. However, since the long-term and short-term rates tend to move together, ADL believes this technique is valid.

APPENDIX I

SUPPORTING DATA FOR INTERNATIONAL COST DIFFERENCES FOR MAJOR PULP AND PAPER PRODUCTS

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TABLE I-1

ENVIRONMENTAL COSTS REPORTED IN 1973 OECD SURVEY

Basis: December 1970 Dollars/Metric Ton and Exchange Rates, Reported 1970/Projected 1975 Costs.

Products and Cost Components	United States	Canada	Sweden
Sulfite Pulp			
Water - Internal	- / -	0.48/5.17	2.59/9.25
- External	2.96/14.14	0.54/4.84	
Air	.51/3.87	0.08/1.21	0.28/0.51
TOTAL	3.47/18.01	0.62/11.22	2.87/9.76
Kraft Pulp and Paper			
Water - Internal	- / -	- /0.63	1.33/4.03
- External	1.45/6.11	0.02/2.83	
Air	.76/5.69	0.01/1.56	.31/1.22
TOTAL	2.21/11.80	0.03/5.02	1.64/5.25
Newsprint			
Water - Internal	- / -	0.05/1.38	3.61/4.78
- External	0.91/3.75	0.28/1.15	
Air	- / -	0.38/1.02	0.01/0.08
TOTAL	0.91/3.75	0.51/3.55	3.62/4.86

SOURCE: "Pollution by the Pulp and Paper Industry," Organization for Economic Cooperation and Development, Paris, 1973.

TABLE I-2

DERIVATION OF SWEDISH WOOD COSTS

Northern Sweden 1974/1975
(August-July season)

Average wood cost for pine and spruce.

120 Sw. Cr./meter solid wood umber bark

Conversion Units:

.363 cunits/m^3

6.50 Sw Cr/$

Southern Sweden 1974/1975 Wood Cost

	Spruce	Pine	Birch	
Sw Cr/m^3	106	106	88	solid m^3 (over bark)
Sw Cr/m^3	117	115	98	(10% bark) (under bark)

$\frac{116}{6.5} \times \frac{1}{.363} = 571$/cunit $\qquad \frac{120}{6.5} \times \frac{1}{.363} = 573$/cunit

Sw Cr/m^3 x 5.15 = Sw Cr/metric ton AD bleached sulfate

5.15 m^3/AD Metric Ton pulp

.363 x 5.15 x .907 = 1.81 cunits/AD short Ton pulp

at 24 lb/ft^3 $\frac{1800}{}$
Bleached yield = 1.81x2400 = 415

SOURCE: Arthur D. Little, Inc., estimates.

DP
/75

TABLE I-1

DERIVATION OF NEWSPRINT WOOD COSTS

U.S. Southeast

1974 $20/BD ton @ 32 lb/ft^3 @ $30.70/AD ton newsprint

@ 62.5 ft^3/BD ton

$20 x $\frac{100}{62.5}$ = $32.00/cunit

1975 Escalate @ 1/5 = $36/cunit wood cost

Wood cost in newsprint =

30.70 x 1.12 = $34.38

U.S. North West and Canada

1975 Costs = $46/cunit logs and chips

2400 lb (BD) cunit

@ $38.33/BD ton

$22/cunit sawdust

2400 lb (BD) cunit

@ $18.33/BD ton

Wood Balance = BDT to produce 1000 ADT newsprint

Sawdust	=	77	x	18.33	=	1411.6
Chips (refiner)	=	308	x	38.33	=	11805.6
Logs (stone)	=	385	x	38.33	=	14757
Logs (Kraft)	=	562.5 x $\frac{186.8}{560}$	=	195x	38.33	= 7474
Chips (Kraft)	=	562.5 x $\frac{186.8}{560}$	=	195x	38.33	= 7474

} average cost/ AD ton newsprint 42.92

SOURCE: Arthur D. Little, Inc., estimates.